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ESTIMATION OF MISSING PRECIPITATION DATA AND COMPLETENESS EVALUATION OF CLIMATE STATION RECORDS FOR SEVERAL SASKATCHEWAN CLIMATE STATIONS

by

E.E. Wheaton

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ABSTRACT

This study illustrates methods to estimate monthly precipitation data to produce the most complete records possible. The literature pertaining to the problem of the treatment of missing data is scarce.

The methods used by the author include a series of systematic steps from completeness analysis, comparison of interstation distance to correlation analysis. The methods culminate in the final estimation procedure, which also contains screening tests to eliminate unsound estimations.

The first step, the completeness analysis, was created by the author to quantify the temporal completeness of the stations' records. This technique provides an objective measure of the stations' temporal adequacies. The mean completeness index for the 85 Saskatchewan stations tested was 76.0%; however eight stations had indices less than 50%.

The second step, the correlation analysis, provided a statistical basis to facilitate the selection of the best stations to use in the estimation procedure. Correlations were found to be surprisingly high, as most coefficients were over 60% and several were over 90%. The strength of the correlation coefficient was affected to a greater degree by interstation distance, rather than by seasonality. An unusual pattern in the seasonality of the correlations was found. It was expected that summer months would have the lowest correlations, but instead the winter months generally had the lowest correlations. The correlations for the summer months were occasionally low, however, but were generally higher than for winter months.

Interstation distance, as well as the completeness and linear corre-

lation analysis were used to rate the stations' suitability for use as an estimator in the estimation procedure.

The estimation calculations were based on the method of ratios, with preceding tests to establish whether the variability of differences was within a tolerable level. One or two additional estimator stations were used if another criterion based on the standard error was passed. The final assessment of estimation was made by comparing the actual and estimated values by means of linear correlation. Correlation coefficients were generally high and significant, most ranging between 70 and 90%.

The estimation procedure resulted in an average increase in completeness of recorded values of 7.3%, with a high value of 28.6%. Stations that were less adequate temporally benefited the most and the most complete stations benefited the least from the estimation procedure.

Thus, as a result of this rigorous systematic methodology, a partially synthesized, and definitely more complete time series of precipitation was obtained for several Saskatchewan climate stations.

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1 INTRODUCTION

In order to facilitate the best comparison between two sets of parameters, excellent records of the parameters must be available. The overall objective of this study is to provide records of monthly precipitation which are as long and as continuous as possible. Given a superior precipitation data base, precipitation data can then be compared to groundwater level trends. This is the use for which this data are being provided.

The study area selected is the province of Saskatchewan, mainly south of 53^{o} North latitude, but a few stations almost as far north as 56^{o} North latitude are also considered. A complete description of the physiography of the study area can be found in the Atlas of Saskatchewan (Richards and Fung 1969).

2 OBJECTIVES

The purposes of this study were as follows:

1) To assess the availability of precipitation data for climate stations near groundwater observation wells.

2) To review available literature pertaining to the problem of temporal gaps.

3) To evaluate the completeness of the climate station records in terms of both lack of missing values and length of record.

4) To select the best climate stations in the vicinity of each groundwater observation well. The best of these were subjected to the estimation procedure to produce records which are as complete as possible.

5) To carry out correlation analyses for all possible pairs of climate stations grouped around groundwater observation wells.

6) To select a sound estimation methodology and apply it to the best climate stations near the wells in order to make those station records even more complete. To determine the reliability of the estimates.

3 LITERATURE REVIEW

Despite the frequent occurrence of missing data, there is a dearth of information concerning the systematic treatment of the problem of temporal gaps (Bennet et al. 1984). Most of the existing literature tends to confront the problem of gaps in a network, that is, spatial gaps, instead of temporal gaps.

There are a few classic works that do refer to the problem of temporal gaps and suggest methods of treatment. These works are by Brooks and Carruthers (1953), Conrad and Pollack (1950) and Thom (1966): they suggest the method of ratios for dealing with missing precipitation records. More recent works in techniques of climatology tend to stress the problem of gaps in the network (Stringer 1972) and statistical models of application to climatology (Ikeda et al. 1980). Other authors (Stidd 1966, Solomon et al. 1968) concentrate their work on the estimations of mean monthly and mean annual precipitation only, as well as emphasizing extrapolation of networks.

It is unfortunate that the subject of temporal gaps has not been given sufficient treatment in past studies. The author devised a method to provide an index of completeness because of the lack of a method to quantify temporal completeness.

4 NATURE OF DATA AND METHODOLOGY

4.1 Introduction

The main obstacles to the effective use of precipitation records are: 1) missing observations in the time sequences of the data, 2) short record lengths of several of the stations.

An examination of the availability and nature of the precipitation data was undertaken before the development of a methodology for their effective use.

4.2 Available Data

The primary source of data for this study was the climatological archives of the Atmospheric Environment Service (AES). The AES has a catalogue (Environment Canada 1981) of the observing programs for the network of climate observing stations across Canada. This data catalogue indicates the observing program, that is, the element(s) observed, the start and end dates of the record, as well as changes in the location and/or changes in the station name and observing program. The record type most commonly maintained for most stations is daily measurements of precipitation and/or extremes (maximum and minimum) of temperature.

The daily data are summarized to produce annual records of monthly values. This was the record type which was used for this study. The data were available for the entire period of record up to the end of the year, 1982.

All of the available climate stations were evaluated initially to determine their suitability in terms of completeness of record and proximity to the observation well. Initial scrutiny revealed that there was

at least two to as many as eight climate stations around each observation well. Stations at an arbitrary distance of more than 50 km away from the station were not selected for use, except for the cases in which they could be used as an estimator station for a station within this distance. The World Meteorological Organization recommends the density of precipitation recording stations to be not greater than 30 km apart (Gandin 1970:16). This restriction would limit the number of comparison stations quite drastically, so the value of 50 km was selected as a limit as at least two stations were available within this distance from most of the wells. If a station was required for the estimation process and no other station was available, this limit would not be strictly adhered to, especially if the correlation was high.

Figure 1 shows the names, location, and distribution of the groundwater observation wells. The spatial distribution of the climate stations, selected because of their proximity to the wells (and their possible use as estimators of other stations), reflect the distribution of the wells. The climate stations are tabulated in Table 1 with their station number, period of record, elevation and location.

Some of the stations included in Table 1 have part of their record under another station code number. A new code number is given to a station in situations such as when its name and/or location have been changed. In cases where changes in instrumentation, observer(s), observing routines, the exposure of instruments and the like occur, the homogeneity of the data may be affected.

The exposure of the instruments may change with a change in location. Local exposure also may change through vegetation growth, urban growth,

Observation Well Name		Location
1	Atton's Lake	NW2-29-44-20-W3
2	Baildon 059	SW4-34-15-26-W2
3	Baildon 060	SE16-15-15-26-W2
4	Bangor "A"	NE16-13-22-3-W2
5	Bangor "B"	NE16-13-22-3-W2
6	Beauval 002	SE9-3-71-12-W3
7	Blucher No. 3	SW4-27-35-2-W3
8	Conquest No. 500	SW13-14-30-9-W3
9	Conquest No. 501	NW4-23-30-10-W3
10	Conquest No. 502	SW12-14-30-10-W3
11	Conquest No. 503	NW12-14-30-10-W3
12	Conquest No. 504	SW12-14-30-10-W3
13	Coronach 001	SW12-15-2-28-W2
14	Crater Lake	NWR-2-23-4-W2
15	Delmeny	SE1-13-38-6-W3
16	Duck Lake No. 1	SE1-33-45-2-W1W3
17	Duck Lake No. 2	SE1-33-45-2-W3
18	Estevan No. 2	SE6-5-4-9-W2
19	Fife Lake 002	SE14-9-3-29-W2
20	Forget	SW12-2-9-7-W2
21	Garden Head	SW13-21-9-19-W3
22	Goodale Farm	SW1-4-36-4-W3
23	Hague	SE8-6-41-2-W3
24	Hearts Hill	NE14-7-36-25-W3
25	Lilac	NE1-2-44-14-W3
26	Melfort	NE8-7-46-17-W2
27	Nokomis	SE3-29-29-22-W2
28	Outram	SE9-22-2-10-W2
29	Riceton	SE3-18-14-17-W2
30	Saskatoon	NW16-8-37-4-W3
31	Shaunavon	NE13-34-8-19-W3
32	Simpson 13-4	SW13-4-29-23-W2
33	Simpson 16-5	SW16-5-29-23-W2
34	Smoky Burn "A"	SE4-1-51-8-W2
35	Smoky Burn "B"	SE4-1-51-8-W2
36	Stenen	SE16-7-33-3-W2
37	Swanson	SW4-15-31-8-W3
38	Tessier	NW13-33-33-11-W3
39	Tyner	SE1-10-24-18-W3
40	Unity	SE1-28-40-21-W3
41	Venscoy	SW12-14-35-8-W3
42	Verlo	SW8-25-16-22-W3
43	Warman	NE13-9-39-5-W3
44	Yorkton 517	SW2-21-25-4-W3
45	Yorkton 519	SW2-21-25-4-W3

Hydrometric Stations		
A.	Crater Lake	NW8-2-23-4-W2
B.	Fife Lake	SE14-9-3-29-W2
C.	Hague	SW3-6-41-2-W3
D.	York Lake 518	SW2-21-25-4-W2

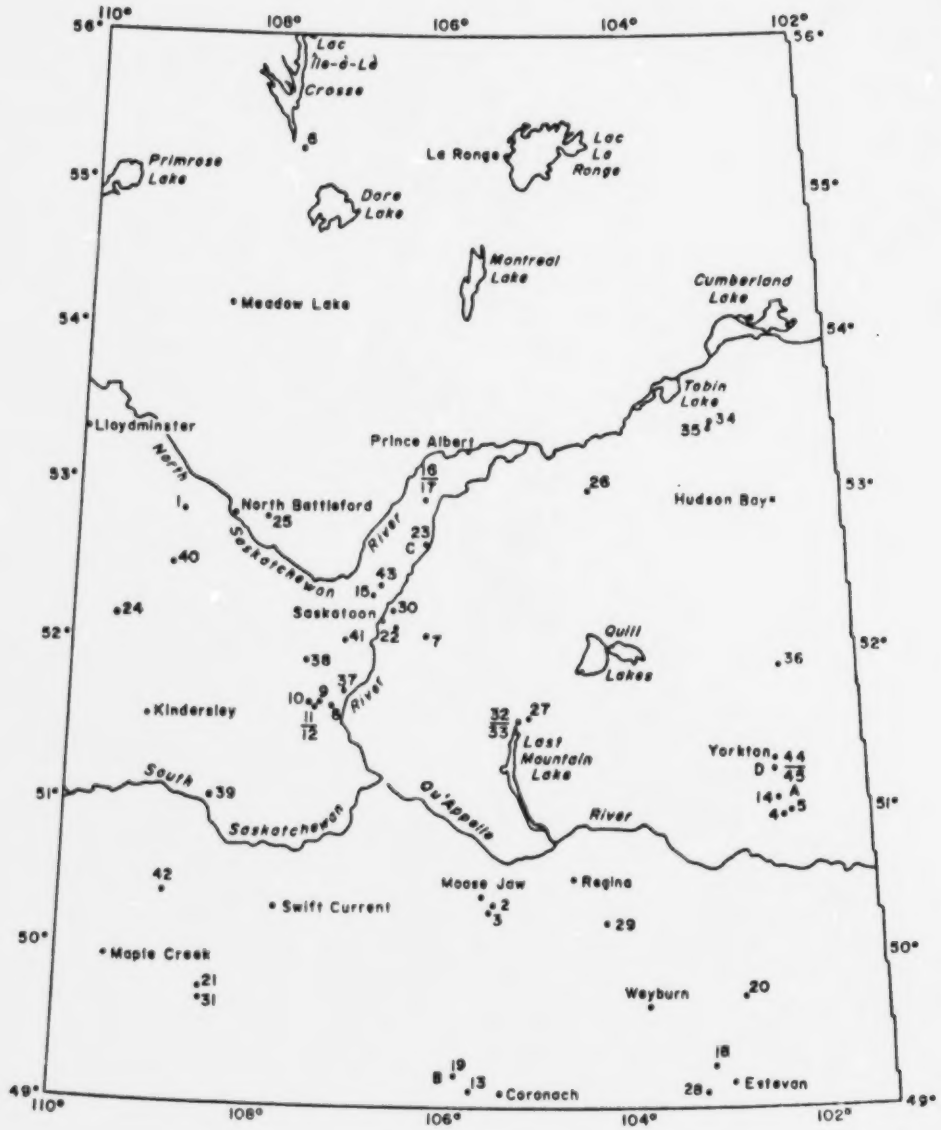

Fig. 1 Location of observation wells and hydrometric stations Source: Meneley et al. (1979)

Table 1. Saskatchewan Climate Stations Used in the Study.

Station Name	Station Number	Operative Period (Year)		Elevation (metres)	Location (in degrees and minutes)	
		First	Last		Latitude	Longitude
Bangor	4010400	1951	1976	532	50 51	102 14
Broadview	4010878	1904	1938	597	50 23	102 33
Broadview	4010879	1965	1982	601	50 23	102 35
Canora	4011095	1965	1982	489	51 38	102 24
Carlyle	4011160	1922	19[illegible]	633	49 38	102 17
Claybank	4011580	1957	1976	643	50 03	105 13
Davidson	4012120	1922	1982	619	51 16	105 59
Duval	4012300	1957	1982	591	51 10	104 51
Estevan	4012390	1899	1944	566	49 12	103 04
Estevan A	4012400	1944	1982	572	49 04	103 00
Francis	4012720	1922	1982	603	50 07	103 55
Guernsey	4013038	1973	1982	530	51 48	105 17
Guernsey CDA EPF	4013040	1951	1965	541	51 49	105 14
Hubbard	4013280	1908	1971	663	51 05	103 24
Humboldt	4013400	1879	1982	568	52 12	105 07
Humboldt	4013401	1974	1982	549	52 16	105 08
Indian Head CDA	4013480	1885	1982	586	50 32	103 40
Indian Head PFRA	4013490	1960	1982	585	50 31	103 41
Kipling	4014040	1949	1982	659	50 12	102 44
Langenburg	4014145	1959	1979	514	50 46	101 41
Melville	4015100	1956	1980	552	50 57	102 48
Midale	4015160	1922	1982	582	49 24	103 25
Moose Jaw A	4015320	1943	1982	577	50 20	105 33
Moose Jaw CHAB	4015325	1884	1954	599	50 23	105 42
Nokomis	4015560	1922	1982	526	51 31	105 00
Regina A	4016560	1883	1982	577	50 26	104 40
Semans	4017320	1922	1982	562	51 24	104 43
Strasbourg	4017800	1910	1982	548	51 04	104 57
Tugaske	4018160	1922	1982	616	50 52	106 18
Tugaske CDA EPF	4018161	1961	1972	605	50 54	106 18
Watrous	4018640	1953	1982	541	51 40	105 28
Watrous 2	4018645	1963	1966	543	51 40	105 28
Weyburn	4018760	1900	1982	570	49 39	103 50
Whitewood	4018880	1902	1982	584	50 28	102 14
Wilcox	4018920	1952	1979	578	50 06	104 43
Yellow Grass	4019040	1911	1982	579	49 48	104 10
Yorkton	4019070	1884	1945	498	51 11	102 31
Yorkton A	4019080	1941	1982	498	51 16	102 28
Aneroid	4020160	1916	1982	745	49 42	107 18
Assiniboia	4020280	1915	1982	724	49 44	105 56
Beechy	4020560	1926	1982	650	50 46	107 19
Chaplin	4021520	1883	1982	671	50 28	106 39
Eston	4022440	1951	1982	682	51 15	108 46
Fox Valley	4022680	1951	1969	709	50 24	109 26
Garden Head	4022800	1911	1972	905	49 49	108 34
Gravelbourg	4022960	1911	1982	700	49 52	106 33
Gull Lake CDA EPF	4023060	1956	1982	960	49 57	108 28
High Point	4023240	1928	1982	640	50 59	107 56
Hughton	4023360	1922	1973	613	51 14	107 55
Instow	4023520	1950	1976	903	49 43	108 17
Klintonel	4024080	1910	1982	1067	49 41	108 54
Leader	4024160	1922	1969	671	50 53	109 33
Leader 2	4024161	1951	1982	674	50 53	109 32
Pennant	4026040	1922	1982	715	50 32	108 14

Table 1 (Continued)

Station Name	Station Number	Operative Period (Year)		Elevation (metres)	Location (in degrees and minutes)	
		First	Last		Latitude	Longitude
Roadene	4026840	1936	1982	701	50 29	108 45
Shaunavon	4027480	1915	1979	917	49 39	108 24
Shaunavon 3	4027486	1971	1982	884	49 54	108 25
Swift Current	4028035	1885	1938	744	50 20	107 45
Swift Current A	4028040	1938	1982	817	50 17	107 41
Coronach	4031844	1971	1982	831	49 16	105 37
Coronach	4031845	1928	1959	732	49 09	105 33
Eastend CDA EPF	4032320	1951	1966	913	49 31	108 45
Eastend CDA EPF South	4032321	1952	1975	914	49 22	108 46
Eastend 2	4032323	1971	1982	914	49 31	108 49
East Poplar River	4032335	1961	1979	739	49 00	105 25
Minton	4035200	1954	1981	716	49 13	104 41
Nashlyn	4035480	1911	1979	945	49 12	109 31
West Poplar River	4038740	1956	1982	876	49 00	106 23
Biggar	4040600	1917	1982	671	52 04	107 59
Denzil	4042188	1959	1982	685	52 18	109 34
Herschel	4043215	1958	1966	610	51 41	108 18
Kerrobert	4043750	1964	1982	657	51 58	109 05
Kindersley	4043888	1910	1971	681	51 28	109 09
Kindersley KY	4043920	1958	1982	683	51 28	109 10
Macklin	4044800	1918	1979	661	52 20	109 56
North Battleford A	4045600	1942	1982	548	52 46	108 15
Prongua	4046280	1927	1960	563	52 44	108 33
Ruthilda	4047040	1941	1967	695	51 54	108 31
Scott CDA	4047240	1911	1982	660	52 22	108 50
Waseca	4048520	1907	1982	648	53 08	109 24
Asquith	4050275	1961	1981	519	52 08	107 14
Dana CFB	4052070	1965	1982	610	52 17	105 46
Dundurn	4052280	1922	1982	529	51 48	106 30
Hafford	4053080	1951	1982	595	52 44	107 22
Kinistino	4053960	1911	1961	463	52 57	105 01
Melfort	4055080	1901	1960	463	52 52	104 36
Melfort CDA	4055085	1961	1982	480	52 49	104 36
Outlook	4055720	1915	1971	541	51 29	107 03
Outlook PFRA	4055736	1952	1982	541	51 29	107 03
Parkside CDA EPF	4055880	1929	1974	515	53 14	106 35
Pilger	4056120	1911	1982	552	52 25	105 09
Prince Albert	4056230	1884	1942	436	53 10	105 45
Prince Albert A	4056240	1942	1982	428	53 13	105 41
Rosthern	4056920	1910	1970	510	52 40	106 20
Saskatoon A	4057120	1892	1982	501	52 10	106 41
Saskatoon SRC	4057180	1963	1982	497	52 09	106 36
Ile a la Crosse	4063420	1962	1982	421	55 27	107 52
Lac la Ronge	4064130	1921	1982	382	55 08	105 23
La Ronge A	4064150	1959	1982	375	55 09	105 15
Meadow Lake	4065055	1967	1978	481	54 08	108 26
Meadow Lake A	4065058	1977	1982	480	54 08	108 31
Smoky Burn CDA EPF	4077560	1951	1972	361	53 20	103 08
Tisdale	4078080	1954	1981	445	52 52	104 02

Table 1 (Continued)

Station Name	Station Number	Operative Period (Year)		Elevation (metres)	Location (in degrees and minutes)	
		First	Last		Latitude	Longitude
Hudson Bay	4083320	1943	1978	372	52 52	102 24
Hudson Bay A	4083321	1978	1982	358	52 49	102 19
Lintlaw	4084440	1926	1968	611	52 05	103 16
Pelly	4086000	1951	1982	500	52 05	101 52

NOTE: The stations are ordered according to drainage basin (as indicated by the first three digits of their station number) and ordered alphabetically within the drainage basin groupings. This ordering is also used for subsequent tables. The following table provides the name and number for each drainage basin used in this study.

Drainage Basins

Basin Number	Basin Name
401	Assiniboine River
402	South Saskatchewan River
403	Missouri River
404	North Saskatchewan River
405	Saskatchewan Forks
406	Churchill River
407	Lower Saskatchewan River
408	Barrier River

pollution, drainage of water, construction of artificial water bodies and so on.

"A data series is said to be homogeneous if it is a sample from a single population" (Thom 1966:4). When changes occur it is often questionable whether the data can be considered to have come from the same statistical population, and therefore not be representative of that same population. But the AES states that the move from town to the airport, which occurred for many stations, did not destroy the homogeneity of the data (Department of Transport 1967:52).

Therefore, in the cases when a station had two or more station numbers (usually indicating a move over a short distance) the stations were concatenated and used as one series. If there were overlapping records, the most complete overlap was selected for use. An assessment of homogeneity is more crucial when climatic variation is being studied.

4.3 Completeness Analysis

The time series of data were inspected to determine the number of gaps and the length of the time series. This was accomplished by the use of a method developed by the author (Wheaton 1979) to quantify the completeness of data in terms of both the number of missing observations and the length of record for each station. This method yields a numerical index of the completeness of each station in terms of the number of gaps and record length. Thus this index indicates the temporal adequacy of the stations' records.

The completeness indices for each station for monthly total precipitation are listed in Table 2. Completeness indices for rainfall and snow-

Table 2. Completeness Indices for Total Precipitation.

Station Name	Missing Values (Total No. of Months)	Missing Years (Total No.)	Percentage Record Length	Percentage Recorded Values	Completeness Index (%)
Bangor	12	0	26.0	92.6	61.1
Broadview	109	46	33.0	72.5	52.8
Canora	11	0	18.0	94.9	56.5
Carlyle	18	0	61.0	97.5	79.3
Claybank	30	0	20.0	87.5	53.8
Davidson	37	0	61.0	94.9	78.0
Duval	5	0	26.0	98.4	62.2
Estevan	139	10	74.0	84.3	79.2
Francis	59	1	60.0	91.8	75.9
Guernsey	88	7	25.0	70.7	47.9
Hubbard	103	2	62.0	86.2	74.1
Humboldt	219	31	73.0	75.4	74.2
Indian Head	77	1	97.0	93.4	95.2
Kipling	5	0	34.0	98.8	66.4
Langenburg	48	1	20.0	80.0	50.0
Melville	14	0	25.0	95.3	60.2
Midale	7	0	61.0	99.0	80.0
Moose Jaw	138	13	84.0	86.3	85.2
Nokomis	110	1	60.0	84.7	72.4
Regina	34	9	91.0	96.9	93.9
Semans	67	1	60.0	90.7	75.3
Strasbourg	37	9	64.0	95.2	79.6
Tugaske	13	0	61.0	98.2	79.6
Watrous	15	0	30.0	95.8	62.9
Weyburn	82	40	43.0	84.1	63.6
Whitewood	46	14	67.0	94.3	80.6
Wilcox	37	0	28.0	89.0	58.5
Yellow Grass	49	0	72.0	94.3	83.2
Yorkton	243	22	77.0	73.7	75.4
Aneroid	54	4	63.0	92.9	77.9
Assiniboia	252	5	63.0	66.7	64.8
Beechy	84	0	57.0	87.7	72.4
Chaplin	120	1	99.0	89.9	94.4
Eston	54	4	28.0	83.9	56.0
Fox Valley	37	0	19.0	83.8	51.4
Garden Head	23	0	62.0	96.9	79.5
Gravelbourg	74	11	61.0	89.9	75.4
Gull Lake	7	0	27.0	97.8	62.4
High Point	62	1	54.0	90.4	72.2
Hughton	74	8	44.0	86.0	65.0
Instow	51	0	27.0	84.3	55.6
Klintonel	23	0	73.0	97.4	85.2
Leader	51	2	59.0	92.8	75.9
Pennant	56	0	61.0	88.3	74.6
Roadene	43	0	47.0	92.4	69.7
Shaunavon	238	0	68.0	70.8	69.4
Swift Current	18	0	98.0	98.5	98.2
Coronach	60	38	19.0	73.7	46.4
Eastend	15	0	33.0	96.2	64.6
East Poplar River	18	0	19.0	92.1	55.6
Minton	49	5	23.0	82.2	52.6
Naslyn	84	0	69.0	89.9	79.4
West Poplar	30	1	26.0	90.4	58.2

Table 2 (Continued)

Station Name	Missing Values (Total No. of Months)	Missing Years (Total No.)	Percentage Record Length	Percentage Recorded Values	Completeness Index (%)
Biggar	164	3	63.0	78.3	70.7
Denzil	9	0	23.0	96.7	59.9
Herschel	23	1	8.0	76.0	42.0
Kerrobert	9	0	19.0	96.1	57.5
Kindersley	181	0	73.0	79.3	76.2
Macklin	145	1	61.0	80.2	70.6
North Battleford	2	0	41.0	99.6	70.3
Prongua	20	6	28.0	94.0	61.0
Ruthilda	118	3	24.0	59.0	41.5
Scott CDA	9	0	72.0	99.0	85.5
Waseca	23	0	76.0	97.5	86.7
Asquith	15	0	21.0	94.0	57.5
Dana	28	0	18.0	87.0	52.5
Dundurn	40	0	61.0	94.5	77.8
Hafford	50	0	32.0	87.0	59.5
Kinistino	165	20	31.0	55.6	43.3
Melfort	88	0	82.0	91.0	86.5
Outlook	66	0	68.0	91.9	80.0
Parkside	78	14	32.0	79.7	55.8
Pilger	132	1	71.0	84.5	77.8
Prince Albert	38	0	99.0	96.8	97.9
Rosthern	57	13	48.0	90.1	69.1
Saskatoon	63	2	89.0	94.1	91.6
Saskatoon SRC	10	0	20.0	95.8	57.9
Ile a la Crosse	48	2	18.0	77.8	47.9
Lac La Ronge	62	22	40.0	87.1	63.5
Meadow Lake	22	0	16.0	88.5	52.2
Smoky Burn	73	0	21.0	71.0	46.0
Tisdale	105	8	20.0	56.3	38.1
Hudson Bay	15	0	40.0	96.9	68.4
Lintlaw	18	0	43.0	96.5	69.8
Pelly	41	2	30.0	88.6	59.3

NOTE: The stations are ordered alphabetically within drainage basin. Drainage basin names and number are provided at the bottom of Table 1.

fall are in Appendix A. A description of the derivation of each column will illustrate the basis of the concept of this completeness index.

Column one of Table 2 lists the total number of months which have no records for total precipitation over the entire period of record for each station up to and including the year 1982.

Column two gives the total number of missing years within the record length. For instance, a station's record may have started in 1952 but stopped from 1956 to 1958, inclusive. If no other breaks occurred, the number of missing years would be three years.

Column three provides information on the record length. The record length is the range of the first year of record and the last year of record minus the number of missing years. This value was converted to a percentage to make it comparable to the next column, the percent of recorded values. The percentage of record length was derived by dividing the record length by 100, that is, by comparing it to a record length of 100 years.

The percentages of recorded value, column four, were found by subtracting the percentage of missing values from 100% as follows:

$$PRP = 100 - PMP = 100 - \frac{TMP}{TRL} \times 100 \qquad \ldots (1)$$

where: PRP = the percentage of recorded precipitation values;
PMP = the percentage of missing precipitation values;
TMP = the total number of missing values of precipitation (in number of months);
TRL = the total record length (in number of months, to 1982)

The completeness indices for total precipitation are in column five. They were derived by computing the arithmetical mean of the percentage recorded data and the percentage record length. In other words, both absence of gaps and length of record were given equal weight in computa-

tion of the final index. Both aspects are most often equally important in climatological analysis.

The computer program written by the author for the computation of the completeness indices is included in Appendix A.

The completeness indices measure the temporal adequacies of the stations' record lengths and continuity of their records on a scale from 0 to 100%. Thus they provide measures of the reliability of the observed data for climatic analyses. They are indicators of the stations' data as compared to the ideal situation where the record length is very long (100 years in this case) and there are no gaps in the record.

4.4 Correlation Analysis

Further scrutiny of the stations near each observation well was undertaken through the use of linear correlation analysis. Correlation coefficients for monthly and annual amounts of precipitation (rainfall, snowfall and total precipitation) were determined for all possible pairs of stations surrounding each well. The fortran program used to determine the correlations is provided in Appendix B.

The correlation analysis augments the completeness analysis in the demarcation of the strengths and weaknesses of the network of stations around each observation well. The greater the correlations of the data series between a pair of stations, the greater is their mutual representativeness. This analysis can additionally provide the value of a station in a network as a station is said to be redundant if it correlates with another station with a coefficient greater than 95% (Godske 1968: 62). If a pair of stations has a much lower correlation than 95%, more

stations are required to represent that area adequately. The lower the absolute value of the correlation, the greater is the need to continue observations at the existing station and to have more stations added to the network.

The geographical pattern of correlation coefficients can be used to distinguish climatic zones in which similar values and variations, that is, homogeneous zones exist, as well as to distinguish the areas of discontinuity between them.

When correlations are plotted as isopleth maps, steep gradients are associated with marked topographical features or true climatic discontinuities when there are no topographical interferences. Foster (1944:305) states that sharp decreases in correlation coefficients mark areas of usual frontal action and zones of climatic discontinuities. Where correlations change rapidly with distance more stations are required to monitor the rapidly changing climatic element(s). Thus correlation values indicate where stations could be added or where present stations could negate the recording of certain climatic elements.

The correlation analysis is also invaluable in the various estimation procedures in both time and space. Selection of the stations most suitable for use in the estimation of gaps in the missing data for other stations as well as the extension of means from a shorter record to the standard normal is based on the best correlation. Thus the results of this analysis improves the selection of stations to be used as estimators.

Furthermore, if a large area has only a few well correlated stations then it is more likely that they are good estimators of the area even though they may be far apart, than if they were poorly correlated. The

correlations can be used to determine how well and the extent to which records of neighbouring stations can be used to estimate values of other less complete stations.

4.5 Temporal Estimation Procedure

The best estimation of a parameter is not only based on a sound estimation procedure, but also requires the proper selection of neighbouring stations to be used in the estimation procedure. So the foregoing completeness and correlation analyses have provided firm foundations for the estimation procedure.

The procedure for the estimation of monthly sums of precipitation is based on the method of ratios (Conrad and Pollack 1950, Brooks and Carruthers 1953, Thom 1966). There is evidence that the ratio of precipitation sums between two neighbouring stations is quasi-constant. Conrad and Pollack (1950:233) state that the quasi constancy of ratios is made evident, both by means of a general geophysical concept and by experience. Brooks and Carruthers (1953:48) state that with precipitation it is the ratio between the totals at two neighbouring stations which tends to remain constant. Thom (1966:4) says that "it may be shown by theoretical analysis that the classical ratio method is close to optimum for the adjustment of precipitation means. Such adjustments are often made to compensate for missing records and to remove heterogeneities."

More recently, MacKay (personal communication 1984) says that the method of ratios for estimation of monthly precipitation can be applied if there are no complicating factors. The author attempted to reduce the effect of complicating factors such as site representativeness, topo-

graphy and homogeneity by careful screening of stations to be used as estimators.

The closest and most complete station of each station grouping around each well (Table 3) was selected to be estimated. The neighbouring stations to be used as estimators were selected on the basis of their actual and statistical distance (i.e. correlation results) as well as the completeness of their records. The actual correlation coefficients were not provided because the correlations for rainfall, snowfall and total precipitation for all twelve months as well as the annual value were considered. Table B.2 provides an example of the correlation coefficients.

In order to make this selection each group of stations was ordered according to their degree of correlation, completeness, distance and topography. Selection was based on these criteria. If possible, the station with the best of all of these criteria was selected, but this rarely occurred. Therefore it was necessary to priorize the rating criteria. The degree of correlation was given first priority as it is the strongest indicator of the degree of relationship between two stations. Completeness was a second place criterion as it is an indicator of the existence of a corresponding value for estimation. Completeness is only a secondary aspect, however, of station representativeness. Distance and topography were third place criteria because their effect was already reflected by the degree of correlation.

Finally, these criteria were used in combination with one another to select the three best stations to be used as estimators. For example, if a station had a high correlation but a very low completeness index, another station with a high correlation index as well as a better com-

Table 3. Climate Station Groupings for each Groundwater Observation Well (with proximity and correlation ratings).

Observation Well	Climate Stations	Proximity	Correlation Rating
1. Atton's Lake	Prongua	1	*
	North Battleford	1b	b
	Scott	1a	c
	Waseca	2, 3	a
2. Baildon	Regina	1a	*
	Chaplin	3	c
	Claybank	3	--
	Indian Head	2, 3	a
	Moose Jaw	1	b
	Tugaske	3	--
	Wilcox	3	--
4. Bangor	Yorkton	1c	*
	Bangor	1	a
	Broadview	3	--
	Canora	3	b
	Hubbard	3	--
	Langenburg	1b	--
	Melville	1a	c
	Whitewood	2, 3	--
6. Beauval	Ile a La Crosse	1	*
	La Ronge	2, 3	a
	Meadow Lake	3	b
7. Blucher	Saskatoon	1, 2	*
	Asquith	3	b
	Biggar	3	--
	Dana	1b	--
	Dundurn	1c	c
	Guernsey	3	--
	Humboldt	3	--
	Saskatoon SRC	1a	a
8. Conquest	Outlook	1, 2	*
	Davidson	1a	b
	Dundurn	3	a
	Saskatoon	3	c
13. Coronach	East Poplar	1a	*
	Assiniboia	2, 3	--
	Coronach	1	b
	Minton	3	a
	West Poplar	3	c
14. Crater Lake	(As for Number 4)		
16. Duck Lake	Prince Albert	1a, 2	*
	Kinistino	3	c
	Parkside	3	a
	Rosthern	1	b

Table 3 (Continued)

Observation Well	Climate Stations	Proximity	Correlation Rating
18. Estevan	Estevan	1	*
	Carlyle	3	a
	Kipling	3	X
	Midale	1a, 2	b
	Weyburn	3	c
19. Fife Lake	(As for Number 13)		
20. Forget	Carlyle	1	*
	Estevan	3	--
	Kipling	1a	b
	Midale	2, 3	a
	Weyburn	3	c
21. Garden Head	Garden Head	1b	*
	Aneroid	3	--
	Eastend	3	--
	Gull Lake	1c	b
	Instow	1a	--
	Klintonel	2, 3	c
	Shaunavon	1	a
22. Goodale Farm	(As for Number 7)		
23. Hague	Rosthern	1	*
	Hafford	1a	b
	Prince Albert	3	c
	Saskatoon	2, 3	a
24. Heart's Hill	Kerrobert	1	*
	Denzil	3	b
	Kindersley	1c	c
	Macklin	1a	--
	Ruthilda	3	--
	Scott	1b, 2	a
25. Lilac	North Battleford	1, 2	*
	Hafford	1a	c
	Prongua	1b	a
	Scott	3	b
	Waseca	3	--
26. Melfort	Melfort	1, 2	*
	Kinistino	1b	a
	Tisdale	1a	b
27. Nokomis	Nokomis	1	*
	Davidson	3	--
	Duval	3	b
	Guernsey	3	--
	Humboldt	3	--
	Semans	1a	c
	Strasbourg	2, 3	--
	Watrous	1b	a
28. Outram	(As for Number 18)		
30. Saskatoon	(As for Number 7)		

Table 3 (Continued)

Observation Well	Climate Stations	Proximity	Correlation Rating
31. Shaunavon	Shaunavon	1	*
	Aneroid	3	--
	Eastend	3	--
	Garden Head	1c	c
	Gull Lake	1b	a
	Instow	1a	b
	Klintonel	2, 3	--
32. Simpson	(As for Number 27)		
34. Smoky Burn	Smoky Burn	1	*
	Hudson Bay	1a	a
36. Stenen	Lintlaw	1a	*
	Canora	1	c
	Pelly	3	a
	Yorkton	2, 3	b
37. Swanson	(As for Number 8)		
38. Tessier	Dundurn	1a	*
	Asquith	3	b
	Biggar	1	c
	Outlook	3	--
	Saskatoon	2, 3	a
39. Tyner	High Point	1a	*
	Beechy	3	a
	Eston	1	--
	Kindersley	2, 3	c
	Pennant	3	b
40. Unity	Scott	1, 2	*
	Denzil	1a	a
	Macklin	3	c
	Prongua	3	b
41. Vanscoy	(As for Number 7)		
42. Verlo	Roadene	1	*
	Fox Valley	1a	a
	Pennant	1b, 2	b
43. Yorkton	(As for Number 4)		

Notes re: proximity column:

1 - the station closest to the well. Other close stations are labelled 1a, 1b, 1c, in order of increasing distance from the well.
2 - the station with the highest completeness index (i.e. the most complete record).
3 - a neighbouring station, i.e. one that is too far away for direct comparison with the well, but it is still useful for estimation.

Notes re: correlation rating column:

a, b, c, - order of rating of the correlation with the station to be estimated, in decreasing value.
X - not used for estimation as there is no corresponding data.
* - indicates the station chosen for estimation.
-- - correlations were not sufficiently high to use these stations for estimation.

pleteness index was chosen as a better potential estimator. Thus only the best stations were selected to be used in the estimation process to estimate the missing data of a climate station.

The selected estimator stations were further screened according to another criterion. Brooks and Carruthers (1953:50) consider that an essential criterion for the use of an estimator station is that the variability of the ratio of corresponding values at the station to be estimated and the estimator station be less than the variability of the values at the station to be estimated. Thus a neighbouring station (i.e. station A) was used to estimate missing monthly precipitation values at another station (station Q) if the following inequality held true:

$$\frac{\sum_{i=1}^{n} (q_i - \lambda a_i)^2}{\sum_{i=1}^{n} (\bar{q} - q_i)^2} < 1.0 \qquad \ldots (2)$$

where:

$$\lambda = \frac{\sum_{i=1}^{n} q_i}{\sum_{i=1}^{n} a_i}$$

n = the number of years of overlapping records at stations A and Q.
q_i = the annual precipitation totals at station Q for each of the n years.
a_i = the annual precipitation values at the estimator station A for each of the n years.
$\bar{q}$ = the mean annual precipitation for station Q over n years.

Therefore the selected estimator stations were further screened according to another criterion.

After the most appropriate estimator stations were selected, the estimation process could take place. The classical method of ratios was used as follows:

$$q_e = a_m \left[\frac{\bar{q}_n}{\bar{a}_n} \right] \qquad \ldots (3)$$

where: q_e = the estimated monthly precipitation value at station Q
a_m = the corresponding monthly precipitation value at station A, the estimator station, for the same month and year that is missing at station Q.
$\bar{q}_n$ = the mean monthly value at station Q over the period of n overlapping years with station A.
$\bar{a}_n$ = the mean monthly value at station A over the period of n overlapping years with station Q.

The standard errors of estimation of precipitation (rain, snow and total precipitation) values were also calculated for each estimator station:

$$SE = \sqrt{\frac{\sum_{i=1}^{n} (q_i - \lambda b_i)^2}{n(n-1)}} \qquad \ldots (4)$$

where: SE = standard error of estimate.
The other symbols have the same meanings as for equation 2.
b_i = the annual precipitation values at station B for each of the n years of overlap with station Q, the station to be estimated.

The standard error was calculated to determine whether a second estimator should be used. Brooks and Carruthers (1953:51) say that no advantage is gained by using a second station unless the standard error of the estimate is less than $\sqrt{3}$ times the standard error of estimate by the first estimator station. Thus a second station was included if the aforementioned inequality held true.

In cases where more than one station were suitable and available, then they were used to provide additional estimation capability. If an additional station(s) was accepted as an estimator, the values estimated by each of the estimator stations were weighted as suggested by Brooks

and Carruthers (1953). The weightings were calculated according to each station's standard error of estimate in order to obtain the final estimated value:

$$q_e = \frac{1/SE_A \; q_A + 1/SE_B \; q_B}{1/SE_A + 1/SE_B} \qquad \ldots (5)$$

where: q_e = the estimated monthly precipitation value at station Q.
q_A, q_B = the estimated monthly precipitation values using station A and B as estimators.
SE_A, SE_B = the standard errors of estimate of stations A and B.

The fortran program used for estimation procedure is in Appendix C. It is not possible to estimate all missing gaps as in cases where the estimator station does not have corresponding data for a specific month.

The final best estimator stations were thus selected according to the criteria of the lowest variability of ratios and the lowest standard errors.

In order to be able to test the estimation results, actual data and estimates of actual data were compared by means of correlation. This was the final step in the series of assessments of the estimation procedure.

The author recommends the series of approaches for precipitation data reconstruction as described herein. It could, however, also be subjected to yet another test. That test could be a comparison with data estimated by performing eigenvector analysis. There are however, several objectives to eigenvector analysis. One of the primary obstacles is that the mechanics of eigenvectors are not easily explained or understood (Stidd 1966). Also there already are several tests given here, so eigenvector analysis was not used.

5 RESULTS

5.1 Results of the Completeness Analysis

Completeness indices for total precipitation (Table 2) ranged from as low as 38.1% for Tisdale to as high as 97.9% for Prince Albert. Other stations with values almost as low as Tisdale were Ruthilda with 41.5%, Herschel with 42.0% and Kinistino with 43.3%. Also, other stations with high indices were Indian Head with 95.2%, Chaplin with 94.4%, Regina with 93.9% and Saskatoon with 91.6%. The mean completeness index for the 85 stations tested was quite high at 76.0%, although eight stations had indices less than 50.0%.

The two qualities of temporal completeness, length of record and lack of missing values, can be assessed separately with the use of columns three and four. Some stations had only a few missing records, but a short record length. The result of this combination is a low completeness index. A long record length but large number of missing records can also result in a low completeness index. The percentage of recorded values, however, is generally higher than the percentage record length.

The completeness indices for rainfall and snowfall can also be assessed separately. The tables of completeness indices for rainfall and snowfall are in Appendix A. The completeness indices for precipitation appear to be higher for rainfall than for snowfall, but there are exceptions.

5.2 Results of the Correlation Analysis

Most of the correlation coefficients are quite high (i.e. greater than 0.6 to 0.7) and are usually significant, at least at the 5% level

(using student's t test). For example, the correlation of May precipitation for Asquith and Saskatoon is 95.5%, significant at the 1% level (Table 4). Correlations are high even for summer rainfall, an unexpected finding. This finding occurs especially for the station pairs with the highest and most significant correlation coefficient (Table 3). Summer rainfall in the study area was thought to have high spatial variability (and therefore low correlations) due to the sporadic nature of the convective processes operating during the summer.

The correlations for Regina with Moose Jaw and Regina with Wilcox as well as correlations for other station pairs are provided for examples in Table 4. Examples of correlations for several pairs of stations are provided in Appendix B.

Extreme correlations (very low or very high) do occur, however, for winter rainfall and summer snowfall. These are usually not significant due to lack of non-zero values and should be ignored. A few low correlations (.3 to .4) were found most often with spring and fall rainfall and snowfall. For example, the correlation for Prongua and Scott (Table 4) for March snowfall is 36.4% (not significant at 5%). Winter (especially December and January) correlations are also often low, but they usually are significant.

There are also cases of negative correlations. Stol (1982) states that zero and negative correlations have been regularly reported and that the largest negative value for Canada by month is -0.10 (Longley 1974). He says that these usually occur at large distances (greater than 150 km) but some of this study's negative correlations occur at distances less than 50 km. For example, Beechy and High Point have a correlation of

Table 4. Correlation Coefficients for Station Pairs (some examples).

Asquith and Saskatoon

CORRELATION OF MONTHLY PRECIPITATION DATA FOR STATIONS. 4050275 AND 4057120

JANUARY	RAINFALL	N = 20	R = 0.691	S.E.= 0.123	T= 4.054	
JANUARY	SNOWFALL	N = 20	R = 0.826	S.E.= 0.075	T= 6.206	
JANUARY	PRECIPITATION	N = 20	R = 0.755	S.E.= 0.101	T= 4.887	
FEBRUARY	RAINFALL	N = 20	R = 0.666	S.E.= 0.131	T= 3.787	
FEBRUARY	SNOWFALL	N = 20	R = 0.881	S.E.= 0.053	T= 7.903	
FEBRUARY	PRECIPITATION	N = 20	R = 0.846	S.E.= 0.067	T= 6.730	
MARCH	RAINFALL	N = 20	R = 0.914	S.E.= 0.039	T= 9.544	
MARCH	SNOWFALL	N = 20	R = 0.950	S.E.= 0.023	T= 12.843	
MARCH	PRECIPITATION	N = 20	R = 0.933	S.E.= 0.031	T= 10.986	
APRIL	RAINFALL	N = 20	R = 0.858	S.E.= 0.062	T= 7.076	
APRIL	SNOWFALL	N = 20	R = 0.877	S.E.= 0.055	T= 7.733	
APRIL	PRECIPITATION	N = 20	R = 0.873	S.E.= 0.056	T= 7.608	
MAY	RAINFALL	N = 20	R = 0.959	S.E.= 0.019	T= 14.416	
MAY	SNOWFALL	N = 20	R = 0.706	S.E.= 0.118	T= 4.225	
MAY	PRECIPITATION	N = 20	R = 0.955	S.E.= 0.021	T= 13.602	
JUNE	RAINFALL	N = 20	R = 0.760	S.E.= 0.099	T= 4.966	
JUNE	SNOWFALL	N = 20	R = ******	S.E.= ******	T= 4.966	
JUNE	PRECIPITATION	N = 20	R = 0.760	S.E.= 0.099	T= 4.966	
JULY	RAINFALL	N = 19	R = 0.536	S.E.= 0.173	T= 2.616	
JULY	SNOWFALL	N = 19	R = ******	S.E.= ******	T= 2.616	
JULY	PRECIPITATION	N = 19	R = 0.536	S.E.= 0.173	T= 2.616	
AUGUST	RAINFALL	N = 20	R = 0.757	S.E.= 0.101	T= 4.914	
AUGUST	SNOWFALL	N = 20	R = ******	S.E.= ******	T= 4.914	
AUGUST	PRECIPITATION	N = 20	R = 0.757	S.E.= 0.101	T= 4.914	
SEPTEMBER	RAINFALL	N = 20	R = 0.869	S.E.= 0.058	T= 7.465	
SEPTEMBER	SNOWFALL	N = 20	R = 0.474	S.E.= 0.183	T= 2.286	
SEPTEMBER	PRECIPITATION	N = 20	R = 0.869	S.E.= 0.058	T= 7.468	
OCTOBER	RAINFALL	N = 19	R = 0.872	S.E.= 0.058	T= 7.329	
OCTOBER	SNOWFALL	N = 19	R = 0.917	S.E.= 0.039	T= 9.451	
OCTOBER	PRECIPITATION	N = 19	R = 0.948	S.E.= 0.025	T= 12.285	
NOVEMBER	RAINFALL	N = 19	R = 0.790	S.E.= 0.091	T= 5.322	
NOVEMBER	SNOWFALL	N = 19	R = 0.914	S.E.= 0.040	T= 9.292	
NOVEMBER	PRECIPITATION	N = 19	R = 0.959	S.E.= 0.019	T= 14.019	
DECEMBER	RAINFALL	N = 20	R = 0.923	S.E.= 0.035	T= 10.196	
DECEMBER	SNOWFALL	N = 20	R = 0.617	S.E.= 0.146	T= 3.323	
DECEMBER	PRECIPITATION	N = 20	R = 0.473	S.E.= 0.183	T= 2.276	
YEARLY TOTAL	RAINFALL	N = 18	R = 0.736	S.E.= 0.115	T= 4.346	
YEARLY TOTAL	SNOWFALL	N = 18	R = 0.757	S.E.= 0.107	T= 4.632	
YEARLY TOTAL	PRECIPITATION	N = 18	R = 0.709	S.E.= 0.124	T= 4.025	

NOTE: N = number of years
R = linear correlation coefficient
S.E.= standard error of estimate
T = the students t statistic
****** = indicates that a value can not be computed

Table 4 (Continued)

Saskatoon and Dundurn

CORRELATION OF MONTHLY PRECIPITATION DATA FOR STATIONS, 4057120 AND 4052280

JANUARY	RAINFALL	N = 54	R = 0.182	S.E.= 0.134	T= 1.333		
JANUARY	SNOWFALL	N = 54	R = 0.586	S.E.= 0.091	T= 5.221		
JANUARY	PRECIPITATION	N = 54	R = 0.554	S.E.= 0.096	T= 4.802		
FEBRUARY	RAINFALL	N = 51	R = 0.481	S.E.= 0.110	T= 3.837		
FEBRUARY	SNOWFALL	N = 52	R = 0.756	S.E.= 0.061	T= 8.175		
FEBRUARY	PRECIPITATION	N = 51	R = 0.756	S.E.= 0.061	T= 8.080		
MARCH	RAINFALL	N = 56	R = 0.257	S.E.= 0.127	T= 1.957		
MARCH	SNOWFALL	N = 56	R = 0.677	S.E.= 0.074	T= 6.759		
MARCH	PRECIPITATION	N = 56	R = 0.636	S.E.= 0.081	T= 6.061		
APRIL	RAINFALL	N = 58	R = 0.826	S.E.= 0.042	T= 10.959		
APRIL	SNOWFALL	N = 59	R = 0.668	S.E.= 0.073	T= 6.770		
APRIL	PRECIPITATION	N = 58	R = 0.819	S.E.= 0.044	T= 10.684		
MAY	RAINFALL	N = 60	R = 0.825	S.E.= 0.042	T= 11.121		
MAY	SNOWFALL	N = 60	R = 0.527	S.E.= 0.095	T= 4.721		
MAY	PRECIPITATION	N = 60	R = 0.856	S.E.= 0.035	T= 12.613		
JUNE	RAINFALL	N = 61	R = 0.862	S.E.= 0.033	T= 13.066		
JUNE	SNOWFALL	N = 61	R = ******	S.E.= ******	T= 13.066		
JUNE	PRECIPITATION	N = 61	R = 0.862	S.E.= 0.033	T= 13.066		
JULY	RAINFALL	N = 61	R = 0.453	S.E.= 0.075	T= 6.618		
JULY	SNOWFALL	N = 61	R = ******	S.E.= ******	T= 6.618		
JULY	PRECIPITATION	N = 61	R = 0.453	S.E.= 0.075	T= 6.618		
AUGUST	RAINFALL	N = 61	R = 0.756	S.E.= 0.056	T= 8.872		
AUGUST	SNOWFALL	N = 61	R = ******	S.E.= ******	T= 8.872		
AUGUST	PRECIPITATION	N = 61	R = 0.756	S.E.= 0.056	T= 8.872		
SEPTEMBER	RAINFALL	N = 58	R = 0.874	S.E.= 0.032	T= 13.458		
SEPTEMBER	SNOWFALL	N = 58	R = 0.720	S.E.= 0.064	T= 7.759		
SEPTEMBER	PRECIPITATION	N = 58	R = 0.842	S.E.= 0.039	T= 11.658		
OCTOBER	RAINFALL	N = 58	R = 0.686	S.E.= 0.071	T= 7.056		
OCTOBER	SNOWFALL	N = 57	R = 0.871	S.E.= 0.033	T= 13.140		
OCTOBER	PRECIPITATION	N = 58	R = 0.863	S.E.= 0.034	T= 12.783		
NOVEMBER	RAINFALL	N = 56	R = 0.668	S.E.= 0.075	T= 6.593		
NOVEMBER	SNOWFALL	N = 55	R = 0.724	S.E.= 0.065	T= 7.648		
NOVEMBER	PRECIPITATION	N = 55	R = 0.670	S.E.= 0.076	T= 6.571		
DECEMBER	RAINFALL	N = 55	R = 0.481	S.E.= 0.106	T= 3.991		
DECEMBER	SNOWFALL	N = 55	R = 0.709	S.E.= 0.068	T= 7.310		
DECEMBER	PRECIPITATION	N = 55	R = 0.668	S.E.= 0.076	T= 6.536		
YEARLY TOTAL	RAINFALL	N = 46	R = 0.737	S.E.= 0.069	T= 7.243		
YEARLY TOTAL	SNOWFALL	N = 45	R = 0.636	S.E.= 0.091	T= 5.398		
YEARLY TOTAL	PRECIPITATION	N = 46	R = 0.665	S.E.= 0.084	T= 5.900		

Table 4 (Continued)

Regina and Wilcox

CORRELATION OF MONTHLY PRECIPITATION DATA FOR STATIONS, 4016560 AND 4018920

JANUARY	RAINFALL	N = 24	R = 0.245	S.E.= 0.200	T= 1.183	
JANUARY	SNOWFALL	N = 23	R = 0.793	S.E.= 0.081	T= 5.968	
JANUARY	PRECIPITATION	N = 24	R = 0.727	S.E.= 0.100	T= 4.972	
FEBRUARY	RAINFALL	N = 25	R = 0.585	S.E.= 0.137	T= 3.464	
FEBRUARY	SNOWFALL	N = 24	R = 0.760	S.E.= 0.090	T= 5.481	
FEBRUARY	PRECIPITATION	N = 24	R = 0.692	S.E.= 0.111	T= 4.502	
MARCH	RAINFALL	N = 27	R = 0.943	S.E.= 0.022	T= 14.186	
MARCH	SNOWFALL	N = 26	R = 0.765	S.E.= 0.085	T= 5.815	
MARCH	PRECIPITATION	N = 26	R = 0.703	S.E.= 0.103	T= 4.839	
APRIL	RAINFALL	N = 25	R = 0.769	S.E.= 0.085	T= 5.763	
APRIL	SNOWFALL	N = 25	R = 0.865	S.E.= 0.052	T= 8.269	
APRIL	PRECIPITATION	N = 25	R = 0.756	S.E.= 0.089	T= 5.543	
MAY	RAINFALL	N = 25	R = 0.835	S.E.= 0.063	T= 7.272	
MAY	SNOWFALL	N = 25	R = 0.831	S.E.= 0.065	T= 7.160	
MAY	PRECIPITATION	N = 25	R = 0.863	S.E.= 0.053	T= 8.175	
JUNE	RAINFALL	N = 26	R = 0.683	S.E.= 0.109	T= 4.578	
JUNE	SNOWFALL	N = 26	R = ******	S.E.= ******	T= 4.578	
JUNE	PRECIPITATION	N = 26	R = 0.683	S.E.= 0.109	T= 4.578	
JULY	RAINFALL	N = 25	R = 0.779	S.E.= 0.082	T= 5.961	
JULY	SNOWFALL	N = 25	R = ******	S.E.= ******	T= 5.961	
JULY	PRECIPITATION	N = 25	R = 0.779	S.E.= 0.082	T= 5.961	
AUGUST	RAINFALL	N = 24	R = 0.870	S.E.= 0.052	T= 8.291	
AUGUST	SNOWFALL	N = 26	R = ******	S.E.= ******	T= 8.291	
AUGUST	PRECIPITATION	N = 24	R = 0.870	S.E.= 0.052	T= 8.291	
SEPTEMBER	RAINFALL	N = 25	R = 0.891	S.E.= 0.043	T= 9.435	
SEPTEMBER	SNOWFALL	N = 26	R = 0.994	S.E.= 0.003	T= 43.815	
SEPTEMBER	PRECIPITATION	N = 25	R = 0.890	S.E.= 0.043	T= 9.368	
OCTOBER	RAINFALL	N = 25	R = 0.886	S.E.= 0.045	T= 9.172	
OCTOBER	SNOWFALL	N = 27	R = 0.857	S.E.= 0.053	T= 8.302	
OCTOBER	PRECIPITATION	N = 25	R = 0.939	S.E.= 0.025	T= 13.092	
NOVEMBER	RAINFALL	N = 26	R = 0.709	S.E.= 0.102	T= 4.920	
NOVEMBER	SNOWFALL	N = 26	R = 0.869	S.E.= 0.050	T= 8.613	
NOVEMBER	PRECIPITATION	N = 26	R = 0.814	S.E.= 0.069	T= 6.873	
DECEMBER	RAINFALL	N = 23	R = 0.445	S.E.= 0.175	T= 2.280	
DECEMBER	SNOWFALL	N = 24	R = 0.620	S.E.= 0.131	T= 3.702	
DECEMBER	PRECIPITATION	N = 24	R = 0.541	S.E.= 0.151	T= 3.017	
YEARLY TOTAL	RAINFALL	N = 15	R = 0.844	S.E.= 0.080	T= 5.668	
YEARLY TOTAL	SNOWFALL	N = 16	R = 0.563	S.E.= 0.183	T= 2.546	
YEARLY TOTAL	PRECIPITATION	N = 16	R = 0.832	S.E.= 0.082	T= 5.620	

Table 4 (Continued)

Moose Jaw and Regina

CORRELATION OF MONTHLY PRECIPITATION DATA FOR STATIONS, 4015320 AND 4016560

JANUARY	RAINFALL	N = 32	R = 0.298	S.E.= 0.166	T= 1.710	
JANUARY	SNOWFALL	N = 31	R = 0.748	S.E.= 0.082	T= 6.063	
JANUARY	PRECIPITATION	N = 31	R = 0.835	S.E.= 0.056	T= 8.172	
FEBRUARY	RAINFALL	N = 32	R = 0.430	S.E.= 0.149	T= 2.609	
FEBRUARY	SNOWFALL	N = 31	R = 0.798	S.E.= 0.068	T= 7.122	
FEBRUARY	PRECIPITATION	N = 31	R = 0.654	S.E.= 0.106	T= 4.658	
MARCH	RAINFALL	N = 32	R = 0.434	S.E.= 0.148	T= 2.640	
MARCH	SNOWFALL	N = 31	R = 0.858	S.E.= 0.049	T= 8.979	
MARCH	PRECIPITATION	N = 31	R = 0.801	S.E.= 0.066	T= 7.213	
APRIL	RAINFALL	N = 32	R = 0.802	S.E.= 0.065	T= 7.345	
APRIL	SNOWFALL	N = 32	R = 0.909	S.E.= 0.032	T= 11.934	
APRIL	PRECIPITATION	N = 32	R = 0.808	S.E.= 0.063	T= 7.518	
MAY	RAINFALL	N = 32	R = 0.856	S.E.= 0.049	T= 9.071	
MAY	SNOWFALL	N = 32	R = 0.829	S.E.= 0.057	T= 8.133	
MAY	PRECIPITATION	N = 32	R = 0.859	S.E.= 0.048	T= 9.195	
JUNE	RAINFALL	N = 33	R = 0.636	S.E.= 0.107	T= 4.588	
JUNE	SNOWFALL	N = 33	R = ******	S.E.= ******	T= 4.588	
JUNE	PRECIPITATION	N = 33	R = 0.636	S.E.= 0.107	T= 4.588	
JULY	RAINFALL	N = 32	R = 0.694	S.E.= 0.095	T= 5.285	
JULY	SNOWFALL	N = 32	R = ******	S.E.= ******	T= 5.285	
JULY	PRECIPITATION	N = 32	R = 0.694	S.E.= 0.095	T= 5.285	
AUGUST	RAINFALL	N = 33	R = 0.877	S.E.= 0.042	T= 10.157	
AUGUST	SNOWFALL	N = 33	R = ******	S.E.= ******	T= 10.157	
AUGUST	PRECIPITATION	N = 33	R = 0.877	S.E.= 0.042	T= 10.157	
SEPTEMBER	RAINFALL	N = 31	R = 0.859	S.E.= 0.049	T= 9.025	
SEPTEMBER	SNOWFALL	N = 32	R = 0.821	S.E.= 0.060	T= 7.671	
SEPTEMBER	PRECIPITATION	N = 31	R = 0.852	S.E.= 0.051	T= 8.752	
OCTOBER	RAINFALL	N = 33	R = 0.900	S.E.= 0.034	T= 11.477	
OCTOBER	SNOWFALL	N = 33	R = 0.874	S.E.= 0.042	T= 10.038	
OCTOBER	PRECIPITATION	N = 33	R = 0.895	S.E.= 0.036	T= 11.189	
NOVEMBER	RAINFALL	N = 32	R = 0.845	S.E.= 0.052	T= 8.669	
NOVEMBER	SNOWFALL	N = 32	R = 0.869	S.E.= 0.045	T= 9.631	
NOVEMBER	PRECIPITATION	N = 32	R = 0.822	S.E.= 0.059	T= 7.908	
DECEMBER	RAINFALL	N = 32	R = 0.646	S.E.= 0.106	T= 4.633	
DECEMBER	SNOWFALL	N = 32	R = 0.790	S.E.= 0.069	T= 7.046	
DECEMBER	PRECIPITATION	N = 32	R = 0.739	S.E.= 0.083	T= 6.009	
YEARLY TOTAL	RAINFALL	N = 29	R = 0.803	S.E.= 0.068	T= 7.002	
YEARLY TOTAL	SNOWFALL	N = 29	R = 0.858	S.E.= 0.051	T= 8.687	
YEARLY TOTAL	PRECIPITATION	N = 29	R = 0.780	S.E.= 0.075	T= 6.473	

-8.6% in January for rainfall. This is likely due to the rare occurrences of January rainfall, coupled with the fact that the interstation distances are close to the 50 km limit. There are a few other negative correlations, usually for January rainfall, although May and October snowfalls for Hubbard with Yorkton and Midale with Estevan provide examples of exceptions.

The seasonal variation of the correlation coefficient appears to be quite sporadic, although a weak general pattern can be discerned. As indicated previously; winter (December, January and February) correlations are low, usually the lowest of all monthly values for all three parameters of rainfall, snowfall and precipitation. Secondary lows are to be found in the summer months (June, July and August), although this was not as consistent as the winter lows and correlations of 80% or higher can be found for these months. Higher values occur for the spring months (mainly for total precipitation), especially March and the fall months, especially September and October.

Imposed upon the pattern of seasonal variation is the stronger pattern of spatial variation. The seasonal variation is exhibited only in relative terms, that is, lower or higher as the distance factor dominates. For instance if the interstation distance is high, even the lower winter values can be higher than the highest correlations for a station pair with a larger interstation distance. An analysis of the relationship between interstation distance and the strength of the correlation showed that for almost 60% of the station groupings (Table 3) the best correlated pair had the smallest interstation distance and over 90% of the groupings had the best correlations for the station pairs which had the smallest or second smallest interstation distance.

5.3 Results of the Estimation Procedure

The best stations in each of the groupings (Table 3) were selected for estimation. The best stations were considered to have a combination of the highest correlation coefficients and completeness indices as well as being the closest to a groundwater well.

The test of the estimation procedure by correlation analysis resulted in quite consistent results. Correlation coefficients were generally high, few being lower than 0.6 and most ranged between 0.7 and 0.9. The correlations that did drop as low as around 0.4 were mostly for rare phenomena such as winter rainfall and summer snowfall. Also most of the correlations were significant, except for stations with few overlapping years or for winter rainfall and summer snowfall.

The results of the estimation, in terms of quantity of gaps recogstructed, is given in Table 5. The increases in the completeness index ranged from as low as 0.1%, almost negligible, to as high as 14.3%.

The low values of improvement often occurred when gaps exist near the beginning of a record and comparable records for the estimators do not exist. The percentage of gaps estimated, however, was often high, even for stations with low increases in their completeness indices. Regina, for example, had 68.5% of missing values filled. Only a small increase in the completeness index resulted because the 98 gaps estimated (total precipitation) are such a small proportion of the existing data.

Considering the estimation procedure resulted primarily in an increase in percentage of recorded values rather than record length, this difference should have more consideration. The increase in recorded values (Table 5) ranges from 0 to 28.6% with a mean value of 7.3%. So some of the stations, usually those that were less complete before esti-

Table 5. Completeness Indices for Total Precipitation After Estimation.

Station Name	Missing Values (Total No. of Months)	Percentage Record Length	Percentage Recorded Values	Completeness Index (%)	Increase in Completeness Index	Increase in Recorded Values
Carlyle	4	61.0	99.5	80.2	0.9	2.0
Estevan	57	84.0	94.3	89.2	10.0	10.0
Nokomis	24	61.0	96.7	78.9	6.5	12.0
Regina	44	100.0	96.9	98.2	4.3	0.0
Yorkton*						
Garden Head	3	62.0	99.6	80.8	1.3	2.7
High Point	5	55.0	99.2	77.1	4.9	8.8
Roadene	3	47.0	99.5	73.2	3.5	7.1
Shaunavon	5	68.0	99.4	83.7	14.3	28.6
East Poplar*						
Kerrobert	0	19.0	100.0	59.5	2.0	3.9
North Battleford	1	41.0	99.8	70.4	0.1	0.2
Prongua	0	34.0	100.0	67.0	6.0	6.0
Dundurn	0	61.0	100.0	80.5	2.1	5.5
Melfort	87	82.0	91.2	86.6	0.1	0.2
Outlook*						
Prince Albert*						
Rosthern	17	61.0	97.7	79.3	10.2	7.6
Saskatoon	83	91.0	94.1	91.7	0.1	0.0
Ile a la Crosse	50	21.0	80.2	50.6	2.7	2.4
Smoky Burn	6	22.0	97.7	59.9	13.9	26.7
Lintlaw*						

*Not available

mation improved greatly, and others - usually those that were more complete, benefited the least from the estimation procedure.

The monthly precipitation series of the estimated stations are an improved data base as a result of the estimation procedure, and thus provide a more suitable basis for subsequent comparisons with other parameters.

6 CONCLUSIONS

In conclusion, several systematic steps were taken to examine the data to provide a suitable setting for the estimation procedure in terms of the best stations to use as estimators.

The completeness analysis was fruitful, revealing several very complete stations to be used as estimators. This proved to be a very useful quantitative method by which to compare the two main temporal characteristics of so many stations.

The correlation analysis revealed surprisingly consistently high and significant correlations. There were, however, several low correlations for stations which had a large interstation distance and for rare phenomena like winter rainfall and summer snowfall. Interstation distance dominated over seasonal variation in affecting the strength of the correlations. Another surprising finding was the strength of the summer correlations, often being higher than winter correlations.

The estimation procedure, utilizing a series of rigorous tests, resulted in many gaps in the time series of the data being synthesized. This reconstruction also occurred with a good degree of confidence as a result of the careful selection and screening of the entire procedure at each stage.

7 RECOMMENDATIONS

Further examination of the correlation coefficients by mapping would provide more information about the spatial characteristics of precipitation and the adequacy of the network of precipitation stations. This might even prove useful in evaluating the relative dominance of the different precipitation mechanisms.

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APPENDIX A

COMPLETENESS ANALYSIS

Table A.1 Completeness Indices for Monthly Rainfall Data.

Station Number	Missing Values (Total No. of Months)	Missing Years (Total No.)	Percentage Record Length	Percentage Recorded Values	Completeness Index ( )
4010400	13	0	26.0	95.8	60.9
4010878	105	20	15.0	41.7	28.3
4010879	3	0	18.0	98.6	58.3
4011095	11	0	18.0	94.9	56.5
4011160	22	0	61.0	97.0	79.0
4011580	29	0	20.0	87.9	54.0
4012120	35	0	61.0	95.2	78.1
4012300	5	0	26.0	98.4	62.2
4012390	112	10	36.0	74.1	55.0
4012400	10	0	39.0	97.9	68.4
4012720	52	1	60.0	92.8	76.4
4013038	6	0	10.0	95.0	52.5
4013040	73	0	15.0	59.4	37.2
4013280	100	2	62.0	86.6	74.3
4013400	212	31	65.0	72.8	68.9
4013401	14	0	9.0	87.0	48.0
4013480	76	1	97.0	93.5	95.2
4014040	4	0	34.0	99.0	66.5
4014145	46	1	20.0	80.8	50.4
4015100	14	0	25.0	95.3	60.2
4015160	8	0	61.0	98.9	80.0
4015320	22	6	34.0	94.6	64.3
4015325	66	7	64.0	91.4	77.7
4015560	94	1	60.0	86.9	73.5
4016560	32	9	91.0	97.1	94.0
4017320	70	0	61.0	90.4	75.7
4017800	37	9	64.0	95.2	79.6
4017816	25	0	10.0	79.2	44.6
4018160	11	0	61.0	98.5	79.7
4918640	8	0	30.0	97.8	63.9
4018760	82	37	46.0	85.1	65.6
4018880	42	14	67.0	94.8	80.9
4018920	36	0	28.0	89.3	58.6
4019040	46	0	72.0	94.7	83.3
4019070	199	22	40.0	58.5	49.3
4019080	8	0	42.0	98.4	70.2
4020160	52	4	63.0	93.1	78.1
4020280	251	5	63.0	66.8	64.9
4020560	80	0	57.0	88.3	72.7
4021520	115	1	99.0	90.3	94.7
4022440	53	4	28.0	84.2	56.1
4022680	40	0	19.0	82.5	50.7
4022800	21	0	62.0	97.2	79.6
4022960	70	11	61.0	90.4	75.7
4023060	7	0	27.0	97.8	62.4
4023240	60	1	54.0	90.7	72.4
4023360	51	8	44.0	90.3	67.2
4023520	48	0	27.0	85.2	56.1
4024080	23	0	73.0	97.4	85.2
4024160	23	0	48.0	96.0	72.0
4024161	31	2	30.0	91.4	60.7
4026040	78	0	61.0	89.3	75.2
4026840	41	0	47.0	92.7	69.9
4027480	213	0	65.0	72.7	68.8

Table A.1 (Continued)

Station Number	Missing Values (Total No. of Months)	Missing Years (Total No.)	Percentage Record Length	Percentage Recorded Values	Completeness Index (%)
4027486	8	0	12.0	94.4	53.2
4028035	16	0	54.0	97.5	75.8
4028040	6	0	45.0	98.9	71.9
4031844	5	0	12.0	96.5	54.3
4031845	51	25	7.0	39.3	23.1
4032320	17	0	16.0	91.1	53.6
4032321	46	0	24.0	84.0	54.0
4032323	12	0	12.0	91.7	51.8
4032335	14	0	19.0	93.9	56.4
4035200	49	5	23.0	82.2	52.6
4035480	61	0	69.0	92.6	80.8
4038740	30	1	26.0	90.4	58.2
4040600	155	3	63.0	79.5	71.2
4042188	8	0	23.0	97.1	60.1
4043215	23	1	8.0	76.0	42.0
4043750	9	0	19.0	96.1	57.5
4043888	182	0	62.0	75.5	68.8
4043920	7	0	25.0	97.7	61.3
4044800	146	1	61.0	80.1	70.5
4045600	2	0	41.0	99.6	70.3
4046280	19	6	28.0	94.3	61.2
4047040	103	3	23.0	62.7	42.8
4047240	8	0	72.0	99.1	85.5
4048520	23	0	76.0	97.5	86.7
4050275	15	0	21.0	94.0	57.5
4052070	28	0	18.0	87.0	52.5
4052280	39	0	61.0	94.7	77.8
4053080	44	0	32.0	88.5	60.3
4053960	63	20	31.0	83.1	57.0
4055080	86	0	60.0	88.1	74.0
4055085	1	0	22.0	99.6	60.8
4055720	33	0	57.0	95.2	76.1
4055722	16	0	4.0	66.7	35.3
4055736	38	0	31.0	89.8	60.4
4055880	77	14	32.0	79.9	56.0
4056120	126	1	71.0	85.2	78.1
4056230	27	0	59.0	96.2	77.6
4056240	11	0	41.0	97.8	69.4
4056920	47	13	48.0	91.8	69.9
4057120	44	2	89.0	95.9	92.4
4057180	10	0	20.0	95.8	57.9
4063420	56	2	19.0	75.4	47.2
4064130	70	21	41.0	85.8	63.4
4064150	19	5	19.0	91.7	55.3
4065055	22	0	12.0	84.7	48.4
4065058	9	0	6.0	87.5	46.8
4077560	75	0	22.0	71.6	46.8
4078080	91	8	20.0	62.1	41.0

Table A.1 (Continued)

Station Number	Missing Values (Total No. of Months)	Missing Years (Total No.)	Percentage Record Length	Percentage Recorded Values	Completeness Index (%)
4083320	10	0	36.0	97.7	66.8
4083321	9	0	5.0	85.0	45.0
4084440	16	0	43.0	96.9	69.9
4086000	39	2	30.0	89.2	59.6

NOTE: Stations with more than one number have not been concatenated for this table.

Table A.2 Completeness Indices for Monthly Snowfall Data.

Station Number	Missing Values (Total No. of Months)	Missing Years (Total No.)	Percentage Record Length	Percentage Recorded Values	Completeness Index (%)
4010400	14	0	26.0	95.5	60.8
4010878	112	19	16.0	41.7	28.8
4010879	3	0	18.0	98.6	58.3
4011095	11	0	18.0	94.9	56.5
4011160	21	0	61.0	97.1	79.1
4011580	26	0	20.0	89.2	54.6
4012120	39	0	61.0	94.7	77.8
4012300	4	0	26.0	98.7	62.4
4012390	134	10	36.0	69.0	52.5
4012400	11	0	39.0	97.6	68.3
4012720	56	1	60.0	92.2	76.1
4013038	5	0	10.0	95.8	52.9
4013040	78	0	15.0	56.7	35.8
4013280	99	2	62.0	86.7	74.3
4013400	204	31	65.0	73.8	69.4
4013401	13	0	9.0	88.0	48.5
4013480	73	1	97.0	93.7	95.4
4014040	5	0	34.0	98.8	66.4
4014145	43	1	20.0	82.1	51.0
4015100	15	0	25.0	95.0	60.0
4015160	8	0	61.0	98.9	80.0
4015320	24	6	34.0	94.1	64.1
4015325	138	7	64.0	82.0	73.0
4015560	103	1	60.0	85.7	72.8
4016560	34	9	91.0	96.9	93.9
4017320	63	1	60.0	91.3	75.6
4017800	34	9	64.0	95.6	79.8
4017816	25	0	10.0	79.2	44.6
4018160	13	0	61.0	98.2	79.6
4918640	17	0	30.0	95.3	62.6
4018760	80	40	43.0	84.5	63.7
4018880	43	14	67.0	94.7	80.8
4018920	33	0	28.0	90.2	59.1
4019040	49	0	72.0	94.3	83.2
4019070	239	22	40.0	50.2	45.1
4019080	7	0	42.0	98.6	70.3
4020160	51	4	63.0	93.3	78.1
4020280	248	5	63.0	67.2	65.1
4020560	87	0	57.0	87.3	72.1
4021520	118	1	99.0	90.1	94.5
4022440	54	4	28.0	83.9	56.0
4022680	38	0	19.0	83.3	51.2
4022800	20	0	62.0	97.3	79.7
4022960	71	11	61.0	90.3	75.7
4023060	8	0	27.0	97.5	62.3
4023240	58	1	54.0	91.0	72.5
4023360	72	8	44.0	86.4	65.2
4023520	48	0	27.0	85.2	56.1
4024080	22	0	73.0	97.5	85.2
4024160	26	0	48.0	95.5	71.7
4024161	30	2	30.0	91.7	60.8
4026040	87	0	61.0	88.1	74.6
4026840	33	0	47.0	93.3	70.1
4027480	242	0	65.0	69.0	67.0

Table A.2 (Continued)

Station Number	Missing Values (Total No. of Months)	Missing Years (Total No.)	Percentage Record Length	Percentage Recorded Values	Completeness Index (%)
4027486	8	0	12.0	94.4	53.2
4028035	16	0	54.0	97.5	75.8
4028040	6	0	45.0	98.9	71.9
4031844	5	0	12.0	96.5	54.3
4031845	55	25	7.0	34.5	20.8
4032320	18	0	16.0	90.6	53.3
4032321	48	0	24.0	83.3	53.7
4032323	10	0	12.0	93.1	52.5
4032335	17	0	19.0	92.5	55.8
4035200	48	5	23.0	82.6	52.8
4035480	82	0	69.0	90.1	79.5
4038740	30	1	26.0	90.4	58.2
4040600	166	3	63.0	78.0	70.5
4042188	9	0	23.0	96.7	59.9
4043215	21	1	8.0	78.1	43.1
4043750	9	0	19.0	96.1	57.5
4043888	183	0	62.0	75.4	68.7
4043920	7	0	25.0	97.7	61.3
4044800	147	1	61.0	79.9	70.5
4045600	2	0	41.0	99.6	70.3
4046280	20	6	28.0	94.0	61.0
4047040	105	3	23.0	62.0	42.5
4047240	10	0	72.0	98.8	85.4
4048520	22	0	76.0	97.6	86.8
4050275	15	0	21.0	94.0	57.5
4052070	30	0	18.0	86.1	52.1
4052280	40	0	61.0	94.5	77.8
4053080	50	0	32.0	87.0	59.5
4053960	163	20	31.0	56.2	43.6
4055080	86	0	60.0	88.1	74.0
4055085	1	0	22.0	99.6	60.8
4055720	37	0	57.0	94.6	75.8
4055722	16	0	4.0	66.7	35.3
4055736	37	0	31.0	90.1	60.5
4055880	73	14	32.0	81.0	56.5
4056120	127	1	71.0	85.1	78.0
4056230	27	0	59.0	96.2	77.6
4056240	11	0	41.0	97.8	69.4
4056920	59	13	48.0	89.8	68.9
4057120	60	2	89.0	94.4	91.7
4057180	10	0	20.0	95.8	57.9
4063420	49	2	18.0	77.3	47.7
4064130	62	22	40.0	87.1	63.5
4064150	18	5	19.0	92.1	55.6
4065055	22	0	12.0	84.7	48.4
4065058	9	0	6.0	87.5	46.8
4077560	72	0	21.0	71.4	46.2
4078080	100	8	20.0	58.3	39.2

Table A.2 (Continued)

Station Number	Missing Values (Total No. of Months)	Missing Years (Total No.)	Percentage Record Length	Percentage Recorded Values	Completeness Index (%)
4083320	7	0	36.0	98.4	67.2
4083321	9	0	5.0	85.0	45.0
4084440	18	0	43.0	96.5	69.8
4086000	39	2	30.0	89.2	59.6

NOTE: Stations with more than one number have not been concatenated for this table.

Table A.3 Fortran Program to Calculate the Completeness Indices of Climate Data Records.

```
00010 //SKGNGAP JOB SKG002,ELAINE,NOTIFY=SKG2HM,MSGCLASS=T
00020 //S1 EXEC FORTVCG
00030 //FORT.SYSIN DD *
00040 C       PGM TO SUM THE NUMBER OF GAPS (INDICATED BY -99999M IN THE
00050 C       DATA) AND/OR THE NUMBER OF MISSING YEARS (E.G. 1964
00060 C         TO 1967) BY MONTH.
00061 C      PGM CHANGED MAY 28,84 TO CHANGE RECORD LENGTH FROM RANGE BETWEEN
00062 C       FIRST AND LAST YEAR TO THIS RANGE MINUS  THE NO. OF MISSING YRS.
00065 C         PGM WRITTEN BY E. WHEATON MAY 7,1984.
00066 C       PGM ALSO GIVES RECORD LENGTH, PERCENT RECORDED
00067 C         PRECIP, PERCENT RECORD LENGTH AND COMPLETENESS INDEX.
00070        DIMENSION NGAPS(12)
00075         INTEGER TGAPS, TOTYR
00080         CHARACTER*1 FLAG(12)
00090         INTEGER OSTN,OYR,FYR,LYR
00095        WRITE(6,30)
00100 C INPUT THE FIRST STATION NUMBER AND THE STARTING YEAR
00110 C OF THIS STATION.
00112        NYR=0
00115        TGAPS=0
00116        TOTYR= 0
00117        MISYR= 0
00120          OSTN=4010400
00130         OYR=951
00131        FYR=951
00132        PRL=0
00133        PRP=0
00134        COMI=0
00135        DO 700 K2=1,12
00136 700     NGAPS(K2)=0
00138        NMO=0
00140 100     READ(2,10,END=500) ISTN, IYR, NO, FLAG
00150 10      FORMAT(I7,2I3,12(6X,A))
00160         IF(ISTN.NE.OSTN) GO TO 400
00165 C CHECK FOR THE ELEMENT NUMBER.
00170 110       IF(NO.NE.50) GO TO 100
00171 C      CHECK THE SEQUENCE OF YEARS FOR MISSING YRS.
00175         NYR=IYR-OYR
00177        IF(NYR.GT.1) MISYR = MISYR + (NYR-1)
00190 200     DO 300 I=1,12
00195         IF(FLAG(I).EQ.'M') NGAPS(I)= NGAPS(I)+1
00210 300     CONTINUE
00220         OYR= IYR
00230         GO TO 100
00235 400     DO 420 K1=1,12
00236         TGAPS= TGAPS +NGAPS(K1)
00237 420     CONTINUE
00238        TOTYR= (OYR-FYR) + 1- MISYR
00239        NMO = TOTYR*12
00240         PRL= TOTYR
00242        PRP= 100.0 - (TGAPS*100.0/NMO)
00244        COMI=(PRL+PRP)/2.0
00246        WRITE(6,20) OSTN,TGAPS,MISYR,TOTYR,NMO,PRL,PRP,COMI
00248 20     FORMAT(15X,I7,4I8,3F7.1//)
00250 30     FORMAT( 16X,'COMPLETENESS INDICES FOR TOTAL PRECIPITATION'//)
00252        NYR=0
00270         OSTN=ISTN
00271        TOTYR= 0
00272        FYR= IYR
00273         MISYR= 0
00274         OYR= IYR
00275         TGAPS=0
00276        PRL=0
00277        PRP=0
00278        COMI=0
00279        NMO=0
00280         DO 410 K=1,12
00290         NGAPS(K)=0
00295 410     CONTINUE
00300         GO TO 110
00310 500     STOP
00320         END
00330 //GO.FT02F001  DD  DSN=SKG2HM.PRECIP,UNIT=SYSDA,
00340 // DISP=(OLD,KEEP)
00350 /*
END OF DATA
```

APPENDIX B

CORRELATION ANALYSIS

Table B.1 Fortran Program Used to Calculate Correlation Coefficients of Precipitation for Pairs of Climate Stations*

```
00010 //GARGORE  JOB GK60,'ELAINE',NOTIFY=GL02HM,MSGCLASS=T
00020 //S1 EXEC FORTVCG,REGION=1024K,PARM.GO='SIZE=512000'
00030 //FORT.SYSIN DD *
00040 C      CORRELATE PRECIPITATION DATA FOR PAIR(S) OF STATIONS
00050 C      DIMENSION I(   ,  STATIONS,  YEARS,  MONTHS,  ITEMS)
00060        DIMENSION I(                  10,      110,        13,        3)
00070 C      (MONTHS:12 MONTHS PLUS ONE FOR THE YEAR)
00080 C       (ITEM=: RAINFALL, SNOWFALL AND TOTAL PRECIP)
00090        CHARACTER*16 IHDG(3)/' RAINFALL
00100       *                     ,' SNOWFALL
00110       *                     ,' PRECIPITATION
00120        CHARACTER*16 MNAME(12)/'  JANUARY ',
00130       *    ,'  FEBRUARY ','    MARCH',
00140       *    ,'    APRIL ','      MAY',
00150       *    ,'     JUNE ','     JULY',
00160       *    ,'   AUGUST ','  SEPTEMBER',
00170       *    ,'  OCTOBER ','  NOVEMBER',
00180       *    ,'  DECEMBER ','  YEARLY TOTAL '/
00190        DIMENSION PRECIP(12)
00200        INTEGER YR,MO,STAINA,STNA,STAINB,STNB
00210        INTEGER STN(10),STAT,S
00220        DIMENSION A(110),B(110)
00230        NYR=110
00240 C      INPUT THE NUMBERS OF THE STATIONS TO BE USED
00250 C      STATION NUMBERS SHOULD BE ORDERED IN THE SAME
00260 C       WAY THAT THE STATIONS ARE ORDERED ON THE
00270 C       INPUT DATA.
00272 C      WORKING ON GROUP 39.
00280        STN(1)= 4020560
00290        STN(2)=4023240
00300        STN(3)=4043888
00310        STN(4)=4022440
00320        NSTN= 4
00330 C
00340 C       INITIALIZE THE ARRAY TO -9999.9  (MEANS
00350 C       THAT THE DATA FOR THE ITEM IS MISSING)
00360 200    DO 210 I=1,NSTN
00370        DO 210 J=1,NYR
00380        DO 210 K=1,13
00390        DO 210 L=1,3
00400 210    I(I,J,K,L)=-9999.9
00410 C
00420 C      READ THE DATA (ALL YEARS FOR THE STATIONS INDICATED ABOVE.
00430 C      MISSING DATA ON THE INPUT FILE IS INDICATED BY -99999
00440        S=0
00450        DO 500 I=1,NSTN
00460        STAT=STN(I)
00470        GO TO 270
00480 250    READ(2,3,END=280) S,YR,MO,PRECIP
00490 3      FORMAT(I7,2I3,12(F6.1,1X))
00492        IF(S.EQ.4043920)S=4043888
00500 270    IF(S.EQ.STAT) GO TO 300
00510        GO TO 250
00520 280    WRITE(6,53)STAT
00530 53     FORMAT('-***ERROR: STATION NUMBER',I8,' IS NOT FOUND')
00540         STOP
00560 300    CONTINUE
00570        YR=YR-879
00580        ITEM= MO-47
00590 C
00600         DO 350 MO=1,12
00610 350    I(I,YR,MO,ITEM)=  PRECIP(MO)
00620 400    READ(2,3,END=500) S,YR,MO,PRECIP
```

Table B.1 (Continued)

```
C       IF(S.EQ.-0.49250)S=-0.43800
C       IF(S.EQ.STAT) GO TO 300
500     CONTINUE
C
C
C     COMPUTE ANNUAL TOTALS (ONLY IF 12 MONTHS OF DATA
C         ARE PRESENT.
        DO 600 I=1,NSTN
        WRITE(6,49) STN(I),INDG
49      FORMAT(//,'STATION: ',I7,'      9999.9 INDICATES THAT A ',
     * 'VALUE CANNOT BE COMPUTED (LESS THAN 12 MONTHS OF DATA WAS ',
     * 'PRESENT)'/ 3('       TOTAL',11X)/
     * 5X,3(3X,A)/)
        DO 600 YR=1,NYR
        III=0
        DO 580 ITEM=1,3
        TOTAL=0
        DO 560 MO=1,12
        PRECIP(MO)=T(I,YR,MO,ITEM)
        IF(PRECIP(MO).LT.0.0.OR.PRECIP(MO).GT.999.8) GO TO 570
        TOTAL=TOTAL + PRECIP(MO)
560     CONTINUE
        T(I,YR,13,ITEM)=TOTAL
        III=1
        GO TO 580
570     T(I,YR,MO,ITEM)=-9999.9
580     CONTINUE
C
        IF(III.EQ.0) GOTO 600
        IYR= YR +879
        WRITE(6,50) IYR, (T(I,YR,13,ITEM),ITEM=1,3)
50      FORMAT (' ','1',I3,3(3X,F8.1,8X))
600     CONTINUE
C
C
C       PROVIDE INDICES OF TWO STATIONS FOR WHICH CORRELATIONS
C         ARE TO BE DONE.
        STNA= 4020560
        STNB=4023240
        DO 2200 STNA=1,NSTN
        DO 2100 STNB= STNA +1,NSTN
1010      STATNA= STN(STNA)
        STATNB= STN(STNB)
        WRITE(6,60) STATNA,STATNB
60      FORMAT('1','CORRELATION OF MONTHLY PRECIPITATION DATA ',
     *    'FOR STATIONS,  ',I7,' AND ',I7//'0',38X,'****** (I.E. ALL '
     *,'*''S) INDICATES THAT A VALUE CANNOT BE COMPUTED'//'0')
        DO 2000 MO =1,13
         DO 2000 ITEM=1,3
C       SELECT THOSE YEARS FOR WHICH BOTH STNA AND STNB HAVE
C       DATA (IN MONTH,MO)
        N=0
         DO 1500 YR=1,NYR
        TA=T(STNA,YR,MO,ITEM)
        TB=T(STNB,YR,MO,ITEM)
        IF(TA.LT.0.0.OR.TB.LT.0.0) GO TO 1500
        N=N+1
        A(N)= TA
        B(N)= TB
1500    CONTINUE
C
C       CALCULATE CORRELATION COEFFICIENT,R
        IF(N.LT.2) GO TO 2000
        SA= 0
        SB=0
        SAB=0
```

Table B.1 (Continued)

```
01560         SASQ=0
01570         SBSQ=0
01580          DO 1950 I=1,N
01590         AI=A(I)
01600         BI=B(I)
01610         SA=SA+AI
01620          SB=SB+BI
01630         SAB=SAB+AI*BI
01640         SASQ= SASQ+AI*AI
01645         SBSQ= SBSQ+BI*BI
01650 1950     CONTINUE
01660         ABAR=SA/N
01670         BBAR=SB/N
01680           DENOM=SASQ-N*ABAR*ABAR)*(SBSQ-N*BBAR*BBAR)
01690         IF(DENOM.GT.0.) GO TO 1960
01700         R=1.E20
01710         SE=1.E20
01720         GO TO 1970
01740 1960     R=(SAB-N*ABAR*BBAR)/SQRT(DENOM)
01750 C
01760 C          CALCULATE STANDARD ERROR: (1-R*R)/N
01770         SE=(1-R*R)/N
01772 C       CALCULATE T TEST:
01773         XN=N-2
01774         X=(1-R*R)
01775         IF(X.LT.0.0) GO TO 1970
01776         TT= R* SQRT(XN)/SQRT(X)
01780 C
01800 1970       WRITE(6,70) MOHDG(MO),IHDG(ITEM),N,R,SE,TT
01810 70      FORMAT ('-',A,1X,A,'      N = ',I2,'          R = ',F6.3,
01820     *'    S.E.= ',F6.3,' T= ',F6.3)
01830 2000     CONTINUE
01840 2100    CONTINUE
01850 2200    CONTINUE
01860 9000      STOP
01865         END
01870 //GO.FT02F001  DD  DSN=SASG2HM.PRECIP,UNIT=SYSDA,
01880 //     DISP=(OLD,KEEP)
01900 /*
01910 T
END OF DATA
```

*This program was originally written by D. Etcheverry (in 1978, SaskCOMP) as instructed by the author. It was then modified for use with the new climate data format, restricted to precipitation and updated by the author.

Table B.2 Correlations of Monthly Precipitation Data (Rainfall, Snowfall and Total Precipitation) for Pairs of Climate Stations (more examples).

Prince Albert and Rosthern

CORRELATION OF MONTHLY PRECIPITATION DATA FOR STATIONS, 4056230 AND 4056920
****** (I.E. ALL *'S) INDICATES THAT A VALUE CANNOT BE COMPUTED

-	JANUARY	RAINFALL	N = 30	R = ******	S.E.= ******	T=	2.514
-	JANUARY	SNOWFALL	N = 29	R = 0.702	S.E.= 0.098	T=	5.115
-	JANUARY	PRECIPITATION	N = 29	R = 0.702	S.E.= 0.098	T=	5.115
-	FEBRUARY	RAINFALL	N = 30	R = 0.015	S.E.= 0.189	T=	0.078
-	FEBRUARY	SNOWFALL	N = 29	R = 0.595	S.E.= 0.124	T=	3.849
-	FEBRUARY	PRECIPITATION	N = 29	R = 0.568	S.E.= 0.130	T=	3.589
-	MARCH	RAINFALL	N = 30	R = 0.129	S.E.= 0.186	T=	0.687
-	MARCH	SNOWFALL	N = 28	R = 0.574	S.E.= 0.132	T=	3.571
-	MARCH	PRECIPITATION	N = 28	R = 0.532	S.E.= 0.141	T=	3.207
-	APRIL	RAINFALL	N = 30	R = 0.582	S.E.= 0.125	T=	3.792
-	APRIL	SNOWFALL	N = 30	R = 0.929	S.E.= 0.026	T=	13.232
-	APRIL	PRECIPITATION	N = 30	R = 0.792	S.E.= 0.070	T=	6.872
-	MAY	RAINFALL	N = 30	R = 0.717	S.E.= 0.092	T=	5.441
-	MAY	SNOWFALL	N = 30	R = 0.458	S.E.= 0.149	T=	2.728
-	MAY	PRECIPITATION	N = 30	R = 0.727	S.E.= 0.089	T=	5.608
-	JUNE	RAINFALL	N = 29	R = 0.643	S.E.= 0.113	T=	4.360
-	JUNE	SNOWFALL	N = 29	R = ******	S.E.= ******	T=	4.360
-	JUNE	PRECIPITATION	N = 29	R = 0.644	S.E.= 0.113	T=	4.378
-	JULY	RAINFALL	N = 29	R = 0.655	S.E.= 0.110	T=	4.510
-	JULY	SNOWFALL	N = 29	R = ******	S.E.= ******	T=	4.510
-	JULY	PRECIPITATION	N = 29	R = 0.655	S.E.= 0.110	T=	4.510
-	AUGUST	RAINFALL	N = 29	R = 0.781	S.E.= 0.075	T=	6.492
-	AUGUST	SNOWFALL	N = 29	R = ******	S.E.= ******	T=	6.492
-	AUGUST	PRECIPITATION	N = 29	R = 0.781	S.E.= 0.075	T=	6.492
-	SEPTEMBER	RAINFALL	N = 28	R = 0.810	S.E.= 0.068	T=	7.031
-	SEPTEMBER	SNOWFALL	N = 28	R = -0.041	S.E.= 0.196	T=	-0.211
-	SEPTEMBER	PRECIPITATION	N = 28	R = 0.799	S.E.= 0.071	T=	6.775
-	OCTOBER	RAINFALL	N = 27	R = 0.861	S.E.= 0.052	T=	8.476
-	OCTOBER	SNOWFALL	N = 28	R = 0.927	S.E.= 0.027	T=	12.651
-	OCTOBER	PRECIPITATION	N = 27	R = 0.846	S.E.= 0.057	T=	7.937
-	NOVEMBER	RAINFALL	N = 29	R = 0.384	S.E.= 0.164	T=	2.160
-	NOVEMBER	SNOWFALL	N = 29	R = 0.821	S.E.= 0.063	T=	7.481
-	NOVEMBER	PRECIPITATION	N = 29	R = 0.831	S.E.= 0.059	T=	7.772
-	DECEMBER	RAINFALL	N = 29	R = 0.487	S.E.= 0.147	T=	2.901
-	DECEMBER	SNOWFALL	N = 28	R = 0.643	S.E.= 0.115	T=	4.286
-	DECEMBER	PRECIPITATION	N = 28	R = 0.627	S.E.= 0.119	T=	4.108
-	YEARLY TOTAL	RAINFALL	N = 24	R = 0.556	S.E.= 0.147	T=	3.134
-	YEARLY TOTAL	SNOWFALL	N = 21	R = 0.818	S.E.= 0.076	T=	6.189
-	YEARLY TOTAL	PRECIPITATION	N = 20	R = 0.674	S.E.= 0.129	T=	3.869

Table B.2 (Continued)

Parkside and Prince Albert

CORRELATION OF MONTHLY PRECIPITATION DATA FOR STATIONS, 4055880 AND 4056230
****** (I.E. ALL #'S) INDICATES THAT A VALUE CANNOT BE COMPUTED

-	JANUARY RAINFALL	N = 7	R = ******	S.E.= ******	T= 0.000	
-	JANUARY SNOWFALL	N = 7	R = 0.494	S.E.= 0.338	T= 1.270	
-	JANUARY PRECIPITATION	N = 7	R = 0.494	S.E.= 0.338	T= 1.270	
-	FEBRUARY RAINFALL	N = 7	R = ******	S.E.= ******	T= 1.270	
-	FEBRUARY SNOWFALL	N = 7	R = 0.860	S.E.= 0.117	T= 3.764	
-	FEBRUARY PRECIPITATION	N = 7	R = 0.722	S.E.= 0.214	T= 2.332	
-	MARCH RAINFALL	N = 7	R = ******	S.E.= ******	T= 2.332	
-	MARCH SNOWFALL	N = 7	R = 0.815	S.E.= 0.150	T= 3.149	
-	MARCH PRECIPITATION	N = 7	R = 0.775	S.E.= 0.178	T= 2.746	
-	APRIL RAINFALL	N = 7	R = -0.220	S.E.= 0.426	T= -0.504	
-	APRIL SNOWFALL	N = 7	R = 0.658	S.E.= 0.254	T= 1.954	
-	APRIL PRECIPITATION	N = 7	R = 0.582	S.E.= 0.296	T= 1.599	
-	MAY RAINFALL	N = 7	R = 0.920	S.E.= 0.068	T= 5.264	
-	MAY SNOWFALL	N = 8	R = -0.223	S.E.= 0.388	T= -0.562	
-	MAY PRECIPITATION	N = 7	R = 0.873	S.E.= 0.106	T= 4.011	
-	JUNE RAINFALL	N = 8	R = 0.794	S.E.= 0.151	T= 3.202	
-	JUNE SNOWFALL	N = 8	R = ******	S.E.= ******	T= 3.202	
-	JUNE PRECIPITATION	N = 8	R = 0.794	S.E.= 0.151	T= 3.202	
-	JULY RAINFALL	N = 8	R = 0.912	S.E.= 0.069	T= 5.429	
-	JULY SNOWFALL	N = 8	R = ******	S.E.= ******	T= 5.429	
-	JULY PRECIPITATION	N = 8	R = 0.912	S.E.= 0.069	T= 5.429	
-	AUGUST RAINFALL	N = 8	R = 0.544	S.E.= 0.287	T= 1.590	
-	AUGUST SNOWFALL	N = 8	R = ******	S.E.= ******	T= 1.590	
-	AUGUST PRECIPITATION	N = 8	R = 0.544	S.E.= 0.287	T= 1.590	
-	SEPTEMBER RAINFALL	N = 8	R = 0.942	S.E.= 0.046	T= 6.897	
-	SEPTEMBER SNOWFALL	N = 8	R = ******	S.E.= ******	T= 6.897	
-	SEPTEMBER PRECIPITATION	N = 8	R = 0.942	S.E.= 0.046	T= 6.881	
-	OCTOBER RAINFALL	N = 8	R = 0.671	S.E.= 0.224	T= 2.217	
-	OCTOBER SNOWFALL	N = 8	R = 0.939	S.E.= 0.049	T= 6.666	
-	OCTOBER PRECIPITATION	N = 8	R = 0.941	S.E.= 0.047	T= 6.783	
-	NOVEMBER RAINFALL	N = 7	R = -0.037	S.E.= 0.447	T= -0.084	
-	NOVEMBER SNOWFALL	N = 7	R = 0.798	S.E.= 0.163	T= 2.959	
-	NOVEMBER PRECIPITATION	N = 7	R = 0.841	S.E.= 0.131	T= 3.475	
-	DECEMBER RAINFALL	N = 7	R = 0.881	S.E.= 0.100	T= 4.158	
-	DECEMBER SNOWFALL	N = 7	R = 0.944	S.E.= 0.048	T= 6.427	
-	DECEMBER PRECIPITATION	N = 7	R = 0.944	S.E.= 0.049	T= 6.381	
-	YEARLY TOTAL RAINFALL	N = 6	R = 0.840	S.E.= 0.148	T= 3.091	
-	YEARLY TOTAL SNOWFALL	N = 6	R = 0.861	S.E.= 0.130	T= 3.382	
-	YEARLY TOTAL PRECIPITATION	N = 6	R = 0.799	S.E.= 0.181	T= 2.656	

Table B.2 (Continued)

Bangor and Yorkton

CORRELATION OF MONTHLY PRECIPITATION DATA FOR STATIONS: 4010400 AND 4019070

****** (I.E. ALL *'S) INDICATES THAT A VALUE CANNOT BE COMPUTED

JANUARY	RAINFALL	N = 25	R = 0.171	S.E.= 0.202	T= 0.831	
JANUARY	SNOWFALL	N = 25	R = 0.842	S.E.= 0.061	T= 7.479	
JANUARY	PRECIPITATION	N = 25	R = 0.854	S.E.= 0.057	T= 7.858	
FEBRUARY	RAINFALL	N = 25	R = 0.563	S.E.= 0.142	T= 3.266	
FEBRUARY	SNOWFALL	N = 24	R = 0.792	S.E.= 0.079	T= 6.093	
FEBRUARY	PRECIPITATION	N = 24	R = 0.789	S.E.= 0.080	T= 6.031	
MARCH	RAINFALL	N = 25	R = 0.591	S.E.= 0.136	T= 3.511	
MARCH	SNOWFALL	N = 25	R = 0.823	S.E.= 0.067	T= 6.942	
MARCH	PRECIPITATION	N = 25	R = 0.866	S.E.= 0.052	T= 8.313	
APRIL	RAINFALL	N = 25	R = 0.703	S.E.= 0.105	T= 4.742	
APRIL	SNOWFALL	N = 25	R = 0.915	S.E.= 0.034	T= 10.876	
APRIL	PRECIPITATION	N = 26	R = 0.791	S.E.= 0.077	T= 6.323	
MAY	RAINFALL	N = 24	R = 0.847	S.E.= 0.060	T= 7.476	
MAY	SNOWFALL	N = 24	R = 0.261	S.E.= 0.199	T= 1.267	
MAY	PRECIPITATION	N = 25	R = 0.876	S.E.= 0.049	T= 8.692	
JUNE	RAINFALL	N = 25	R = 0.882	S.E.= 0.046	T= 8.965	
JUNE	SNOWFALL	N = 25	R = ******	S.E.= ******	T= 8.965	
JUNE	PRECIPITATION	N = 25	R = 0.882	S.E.= 0.046	T= 8.965	
JULY	RAINFALL	N = 25	R = 0.590	S.E.= 0.136	T= 3.500	
JULY	SNOWFALL	N = 25	R = ******	S.E.= ******	T= 3.500	
JULY	PRECIPITATION	N = 25	R = 0.590	S.E.= 0.136	T= 3.500	
AUGUST	RAINFALL	N = 25	R = 0.655	S.E.= 0.119	T= 4.158	
AUGUST	SNOWFALL	N = 25	R = ******	S.E.= ******	T= 4.158	
AUGUST	PRECIPITATION	N = 25	R = 0.655	S.E.= 0.119	T= 4.158	
SEPTEMBER	RAINFALL	N = 25	R = 0.809	S.E.= 0.072	T= 6.608	
SEPTEMBER	SNOWFALL	N = 25	R = 0.960	S.E.= 0.016	T= 16.519	
SEPTEMBER	PRECIPITATION	N = 25	R = 0.819	S.E.= 0.068	T= 6.857	
OCTOBER	RAINFALL	N = 25	R = 0.690	S.E.= 0.109	T= 4.575	
OCTOBER	SNOWFALL	N = 25	R = 0.852	S.E.= 0.057	T= 7.818	
OCTOBER	PRECIPITATION	N = 25	R = 0.764	S.E.= 0.087	T= 5.673	
NOVEMBER	RAINFALL	N = 25	R = 0.719	S.E.= 0.101	T= 4.964	
NOVEMBER	SNOWFALL	N = 25	R = 0.927	S.E.= 0.029	T= 11.881	
NOVEMBER	PRECIPITATION	N = 25	R = 0.908	S.E.= 0.037	T= 10.397	
DECEMBER	RAINFALL	N = 25	R = 0.783	S.E.= 0.081	T= 6.037	
DECEMBER	SNOWFALL	N = 25	R = 0.508	S.E.= 0.155	T= 2.829	
DECEMBER	PRECIPITATION	N = 25	R = 0.470	S.E.= 0.162	T= 2.557	
YEARLY TOTAL	RAINFALL	N = 22	R = 0.900	S.E.= 0.043	T= 9.218	
YEARLY TOTAL	SNOWFALL	N = 22	R = 0.887	S.E.= 0.048	T= 8.599	
YEARLY TOTAL	PRECIPITATION	N = 23	R = 0.880	S.E.= 0.049	T= 8.481	

Table B.2 (Continued)

Yorkton and Canora

CORRELATION OF MONTHLY PRECIPITATION DATA FOR STATIONS, 4019070 AND 4011095
****** (I.E. ALL *'S) INDICATES THAT A VALUE CANNOT BE COMPUTED

-	JANUARY RAINFALL	N = 17	R = ******	S.E.= ******	T=	3.112
-	JANUARY SNOWFALL	N = 17	R = 0.842	S.E.= 0.075	T=	6.041
-	JANUARY PRECIPITATION	N = 17	R = 0.912	S.E.= 0.043	T=	8.614
-	FEBRUARY RAINFALL	N = 17	R = 0.963	S.E.= 0.019	T=	13.848
-	FEBRUARY SNOWFALL	N = 17	R = 0.654	S.E.= 0.148	T=	3.348
-	FEBRUARY PRECIPITATION	N = 17	R = 0.651	S.E.= 0.149	T=	3.326
-	MARCH RAINFALL	N = 17	R = 0.035	S.E.= 0.258	T=	0.136
-	MARCH SNOWFALL	N = 17	R = 0.824	S.E.= 0.083	T=	5.625
-	MARCH PRECIPITATION	N = 17	R = 0.790	S.E.= 0.097	T=	4.989
-	APRIL RAINFALL	N = 17	R = 0.757	S.E.= 0.110	T=	4.483
-	APRIL SNOWFALL	N = 17	R = 0.899	S.E.= 0.050	T=	7.944
-	APRIL PRECIPITATION	N = 17	R = 0.920	S.E.= 0.040	T=	9.100
-	MAY RAINFALL	N = 17	R = 0.794	S.E.= 0.096	T=	5.051
-	MAY SNOWFALL	N = 17	R = 0.725	S.E.= 0.122	T=	4.082
-	MAY PRECIPITATION	N = 17	R = 0.802	S.E.= 0.092	T=	5.201
-	JUNE RAINFALL	N = 16	R = 0.865	S.E.= 0.067	T=	6.453
-	JUNE SNOWFALL	N = 16	R = ******	S.E.= ******	T=	6.453
-	JUNE PRECIPITATION	N = 16	R = 0.865	S.E.= 0.067	T=	6.453
-	JULY RAINFALL	N = 18	R = 0.736	S.E.= 0.115	T=	4.350
-	JULY SNOWFALL	N = 18	R = ******	S.E.= ******	T=	4.350
-	JULY PRECIPITATION	N = 18	R = 0.737	S.E.= 0.114	T=	4.364
-	AUGUST RAINFALL	N = 18	R = 0.637	S.E.= 0.148	T=	3.308
-	AUGUST SNOWFALL	N = 18	R = ******	S.E.= ******	T=	3.308
-	AUGUST PRECIPITATION	N = 18	R = 0.637	S.E.= 0.148	T=	3.308
-	SEPTEMBER RAINFALL	N = 18	R = 0.933	S.E.= 0.032	T=	10.390
-	SEPTEMBER SNOWFALL	N = 18	R = 0.961	S.E.= 0.019	T=	13.830
-	SEPTEMBER PRECIPITATION	N = 18	R = 0.931	S.E.= 0.033	T=	10.176
-	OCTOBER RAINFALL	N = 17	R = 0.828	S.E.= 0.081	T=	5.723
-	OCTOBER SNOWFALL	N = 17	R = 0.910	S.E.= 0.044	T=	8.491
-	OCTOBER PRECIPITATION	N = 17	R = 0.918	S.E.= 0.040	T=	8.981
-	NOVEMBER RAINFALL	N = 16	R = 0.727	S.E.= 0.126	T=	3.963
-	NOVEMBER SNOWFALL	N = 16	R = 0.842	S.E.= 0.078	T=	5.838
-	NOVEMBER PRECIPITATION	N = 16	R = 0.826	S.E.= 0.085	T=	5.484
-	DECEMBER RAINFALL	N = 17	R = 0.146	S.E.= 0.253	T=	0.571
-	DECEMBER SNOWFALL	N = 17	R = 0.563	S.E.= 0.176	T=	2.637
-	DECEMBER PRECIPITATION	N = 17	R = 0.401	S.E.= 0.199	T=	2.122
-	YEARLY TOTAL RAINFALL	N = 12	R = 0.897	S.E.= 0.067	T=	6.076
-	YEARLY TOTAL SNOWFALL	N = 12	R = 0.927	S.E.= 0.045	T=	7.801
-	YEARLY TOTAL PRECIPITATION	N = 12	R = 0.747	S.E.= 0.140	T=	3.550

Table B.2 (Continued)

Parkside and Rosthern

CORRELATION OF MONTHLY PRECIPITATION DATA FOR STATIONS: 4055880 AND 4056920
****** (I.E. ALL *'S) INDICATES THAT A VALUE CANNOT BE COMPUTED

JANUARY	RAINFALL	N = 16	R = ******	S.E.= ******	T=	2.656
JANUARY	SNOWFALL	N = 13	R = 0.574	S.E.= 0.202	T=	2.323
JANUARY	PRECIPITATION	N = 14	R = 0.480	S.E.= 0.222	T=	1.896
FEBRUARY	RAINFALL	N = 19	R = -0.060	S.E.= 0.242	T=	-0.248
FEBRUARY	SNOWFALL	N = 16	R = 0.766	S.E.= 0.110	T=	4.464
FEBRUARY	PRECIPITATION	N = 16	R = 0.769	S.E.= 0.109	T=	4.499
MARCH	RAINFALL	N = 16	R = 0.997	S.E.= 0.002	T=	49.250
MARCH	SNOWFALL	N = 15	R = 0.275	S.E.= 0.256	T=	1.032
MARCH	PRECIPITATION	N = 16	R = 0.231	S.E.= 0.253	T=	0.887
APRIL	RAINFALL	N = 18	R = 0.616	S.E.= 0.155	T=	3.131
APRIL	SNOWFALL	N = 18	R = 0.808	S.E.= 0.087	T=	5.483
APRIL	PRECIPITATION	N = 18	R = 0.816	S.E.= 0.083	T=	5.657
MAY	RAINFALL	N = 20	R = 0.817	S.E.= 0.079	T=	6.001
MAY	SNOWFALL	N = 21	R = 0.161	S.E.= 0.223	T=	0.709
MAY	PRECIPITATION	N = 20	R = 0.794	S.E.= 0.087	T=	5.570
JUNE	RAINFALL	N = 20	R = 0.768	S.E.= 0.097	T=	5.096
JUNE	SNOWFALL	N = 22	R = ******	S.E.= ******	T=	5.096
JUNE	PRECIPITATION	N = 20	R = 0.768	S.E.= 0.097	T=	5.096
JULY	RAINFALL	N = 21	R = 0.286	S.E.= 0.211	T=	1.302
JULY	SNOWFALL	N = 22	R = ******	S.E.= ******	T=	1.302
JULY	PRECIPITATION	N = 21	R = 0.286	S.E.= 0.211	T=	1.302
AUGUST	RAINFALL	N = 21	R = 0.877	S.E.= 0.053	T=	7.958
AUGUST	SNOWFALL	N = 23	R = ******	S.E.= ******	T=	7.958
AUGUST	PRECIPITATION	N = 21	R = 0.877	S.E.= 0.053	T=	7.958
SEPTEMBER	RAINFALL	N = 21	R = 0.822	S.E.= 0.074	T=	6.294
SEPTEMBER	SNOWFALL	N = 22	R = 0.363	S.E.= 0.194	T=	1.743
SEPTEMBER	PRECIPITATION	N = 21	R = 0.829	S.E.= 0.072	T=	6.463
OCTOBER	RAINFALL	N = 20	R = 0.596	S.E.= 0.152	T=	3.153
OCTOBER	SNOWFALL	N = 21	R = 0.943	S.E.= 0.025	T=	12.382
OCTOBER	PRECIPITATION	N = 20	R = 0.910	S.E.= 0.040	T=	9.334
NOVEMBER	RAINFALL	N = 20	R = 0.604	S.E.= 0.150	T=	3.216
NOVEMBER	SNOWFALL	N = 20	R = 0.601	S.E.= 0.151	T=	3.187
NOVEMBER	PRECIPITATION	N = 21	R = 0.613	S.E.= 0.143	T=	3.382
DECEMBER	RAINFALL	N = 18	R = 0.767	S.E.= 0.103	T=	4.784
DECEMBER	SNOWFALL	N = 15	R = 0.766	S.E.= 0.115	T=	4.297
DECEMBER	PRECIPITATION	N = 15	R = 0.766	S.E.= 0.115	T=	4.297
YEARLY TOTAL	RAINFALL	N = 8	R = 0.511	S.E.= 0.302	T=	1.456
YEARLY TOTAL	SNOWFALL	N = 8	R = 0.660	S.E.= 0.230	T=	2.152
YEARLY TOTAL	PRECIPITATION	N = 8	R = 0.716	S.E.= 0.199	T=	2.514

Table B.2 (Continued)

Prongua and Scott

CORRELATION OF MONTHLY PRECIPITATION DATA FOR STATIONS, 4046280 AND 4047240
****** (I.E. ALL *'S) INDICATES THAT A VALUE CANNOT BE COMPUTED

-	JANUARY RAINFALL	N = 27	R = 0.305	S.E.= 0.181	T= 1.603	
-	JANUARY SNOWFALL	N = 26	R = 0.232	S.E.= 0.193	T= 1.170	
-	JANUARY PRECIPITATION	N = 26	R = 0.248	S.E.= 0.192	T= 1.256	
-	FEBRUARY RAINFALL	N = 25	R = 0.907	S.E.= 0.037	T= 10.356	
-	FEBRUARY SNOWFALL	N = 24	R = 0.540	S.E.= 0.151	T= 3.006	
-	FEBRUARY PRECIPITATION	N = 24	R = 0.528	S.E.= 0.154	T= 2.916	
-	MARCH RAINFALL	N = 25	R = 0.478	S.E.= 0.161	T= 2.608	
-	MARCH SNOWFALL	N = 25	R = 0.364	S.E.= 0.181	T= 1.874	
-	MARCH PRECIPITATION	N = 25	R = 0.371	S.E.= 0.180	T= 1.914	
-	APRIL RAINFALL	N = 28	R = 0.735	S.E.= 0.090	T= 5.525	
-	APRIL SNOWFALL	N = 28	R = 0.734	S.E.= 0.090	T= 5.516	
-	APRIL PRECIPITATION	N = 28	R = 0.854	S.E.= 0.053	T= 8.356	
-	MAY RAINFALL	N = 27	R = 0.792	S.E.= 0.075	T= 6.478	
-	MAY SNOWFALL	N = 27	R = 0.370	S.E.= 0.173	T= 1.994	
-	MAY PRECIPITATION	N = 27	R = 0.796	S.E.= 0.073	T= 6.572	
-	JUNE RAINFALL	N = 27	R = 0.903	S.E.= 0.037	T= 10.484	
-	JUNE SNOWFALL	N = 27	R = ******	S.E.= ******	T= 10.484	
-	JUNE PRECIPITATION	N = 27	R = 0.903	S.E.= 0.037	T= 10.484	
-	JULY RAINFALL	N = 26	R = 0.748	S.E.= 0.090	T= 5.526	
-	JULY SNOWFALL	N = 26	R = ******	S.E.= ******	T= 5.526	
-	JULY PRECIPITATION	N = 26	R = 0.748	S.E.= 0.090	T= 5.526	
-	AUGUST RAINFALL	N = 26	R = 0.875	S.E.= 0.048	T= 8.865	
-	AUGUST SNOWFALL	N = 26	R = ******	S.E.= ******	T= 8.865	
-	AUGUST PRECIPITATION	N = 26	R = 0.875	S.E.= 0.048	T= 8.865	
-	SEPTEMBER RAINFALL	N = 26	R = 0.788	S.E.= 0.077	T= 6.278	
-	SEPTEMBER SNOWFALL	N = 26	R = 0.898	S.E.= 0.039	T= 10.025	
-	SEPTEMBER PRECIPITATION	N = 26	R = 0.803	S.E.= 0.072	T= 6.611	
-	OCTOBER RAINFALL	N = 27	R = 0.897	S.E.= 0.039	T= 10.172	
-	OCTOBER SNOWFALL	N = 27	R = 0.719	S.E.= 0.097	T= 5.173	
-	OCTOBER PRECIPITATION	N = 27	R = 0.932	S.E.= 0.026	T= 12.949	
-	NOVEMBER RAINFALL	N = 26	R = 0.455	S.E.= 0.162	T= 2.504	
-	NOVEMBER SNOWFALL	N = 26	R = 0.762	S.E.= 0.036	T= 5.769	
-	NOVEMBER PRECIPITATION	N = 26	R = 0.680	S.E.= 0.110	T= 4.543	
-	DECEMBER RAINFALL	N = 26	R = 0.942	S.E.= 0.023	T= 13.739	
-	DECEMBER SNOWFALL	N = 26	R = 0.487	S.E.= 0.156	T= 2.732	
-	DECEMBER PRECIPITATION	N = 26	R = 0.491	S.E.= 0.155	T= 2.761	
-	YEARLY TOTAL RAINFALL	N = 24	R = 0.778	S.E.= 0.084	T= 5.807	
-	YEARLY TOTAL SNOWFALL	N = 23	R = 0.511	S.E.= 0.161	T= 2.726	
-	YEARLY TOTAL PRECIPITATION	N = 23	R = 0.533	S.E.= 0.156	T= 2.883	

NOTE: - when a month's heading is not given, this indicates that there was not enough comparable data to compute a correlation.
- this is only a partial set of station pairs provided for more examples. The entire collection was not included as it consists of at least 94 station pairs and was too lengthy to include. It can be obtained on request from the author.

APPENDIX C

ESTIMATION PROCEDURE

Table C-1 Fortran Program Used to Estimate Missing Monthly Precipitation (and test the results)*.

```
00010 //CLG0.SY    JOB 'KG002,ELAINE,NOTIFY=KG2ND,MSGCLASS=T
00020 //G01 EXEC FORTVCG,REGION=1024K,PARM.GO='SIZE=512000'
00030 C      PGM NAME IS ESTN
00040 C      PGM WAS UPDATED JUNE 18/84
00050 C
00060 C      PROGRAM TO ESTIMATE MONTHLY DATA : RAIN, SNOW & TOTAL PRECIP.
00070 C
00080 C      Q IS THE STATION BEING ESTIMATED.
00090 C      A,B AND OPTIONALLY C ARE THE STATIONS USED TO ESTIMATE Q'S DATA.
00100 C
00110 C
00120 C       MONTHLY-DATA($STNS,$YEARS,$MONTHS,$ITEMS)
00130         REAL  MD      (    4,   100,     12,     3)
00140 C
00150 C               STN - 1 FOR Q              ITEM - 1 FOR TOTAL RAINFALL
00160 C                   - 2 FOR A                  - 2 FOR TOTAL SNOWFALL
00170 C                   - 3 FOR B                  - 3 FOR TOTAL PRECIPITA
00180 C
00190         INTEGER MONTH(12)/'JAN.','FEB.','MAR.','APR.','MAY ','JUNE','JUL
00200        *                 ,'AUG.','SEP.','OCT.','NOV.','DEC.'/
00210         REAL*8 ITMTYP(3)/'RAINFALL',
00220        *                 'SNOWFALL','T.PRECIP'/
00230 C
00240         INTEGER FIRSTY,LASTY,OUNIT,ID(4),NORDER(4)
00250         CHARACTER*4 NAMN(4),NAM(4)/'STNQ','STNA','STNB','STNC'/
00260         CHARACTER*1 BLK/' '/
00270         INTEGER QGAPS(100)
00280         INTEGER ESTSTN(3)
00290         DIMENSION Q(100),X(100),RE(100)
00300         INTEGER MOVRLP(4)
00310         REAL MOOVRN(4),DIFVAR(4),SE(4),RATIO(4), CORREL(4),SLE(4)
00320         REAL MXOVRN(4)
00321         REAL TT(4),R,XX
00330         LOGICAL*1 TWO(4,4)/16*.FALSE./
00340 C       TWO( ESTSTN(1),ESTSTN(2) ) = .TRUE.   IF SE(2ND) 'SQRT(3) * SE(1
00350 C                                  = .FALSE.  OTHERWISE.
00360 C       TWO( ESTSTN(1),ESTSTN(3) ) = .TRUE.   IF SE(3RD)  SQRT(3) * SE(1 )
00370 C                                  = .FALSE.  OTHERWISE.
00380 C       TWO( ESTSTN(2),ESTSTN(3) ) = .TRUE.   IF SE(3RD) ( SQRT(3) * SE( .
00390 C                                  = .FALSE.  OTHERWISE.
00400         REAL MISSNG/-9999.9/,PRECIP(12)
00410 C       MISSING DATA IS DENOTED (IN NEW FORMAT TAPES) BY A VALUE OF '-99.
00420         CHARACTER*1 ABRNAM(4)/'Q','A','B','C'/
00430         CHARACTER*1 USED1(100),USED2(100)
00440         DIMENSION IUSE(2),VAL(2)
00450 C                 IUSE WILL CONTAIN THE INDICES OF 'AVAILABLE' STATIONS
00460 C                    TO BE USED TO FILL A GAP.
00470 C                                      VAL : VALUES OF ITEMS FOR 'IUSE'
00471 C                    STATIONS.
00480         REAL ITEM(3)
00490                                                 REAL  RLEVEL/1.0/
00500         SQRT3=SQRT(3.)
00510 C
00520 C
00530 C
00540 C
00550 C
00560 C
00570 C
00580 C
00590 C       INPUT PARAMETERS:
00600 C        - YEAR DATA STARTS (FIRSTY), YEAR DATA ENDS (LASTY)
00610 C        - ID OF Q,  ID OF A,  ID OF B,  ID OF C (OPTIONAL)
00620 C          ORDER OF APPEARANCE FOR STATIONS TO BE READ
00630 C       WITH NEW FORMAT
00640 C          USE '1' FOR Q, '2' FOR A, '3' FOR B, '4' FOR C.
00650 C          FOR EXAMPLE  '4 1 2'  MEANS STNC THEN STNQ THEN STNA.
00660 C
00661 C       TO ESTIMATE SASKATOON
00670         FIRSTY=892
00680         LASTY=982
00690         ID(1)=4057120
00700         ID(2)=4057180
00710          ID(3)=4050275
00711          ID(4)=4052280
00720         NORDER(1)=3
00730         NORDER(2)=1
00740          NORDER(3)=4
00741         NORDER(4)=2
00750 C
00760 C       NSTNS= # OF STATIONS.
00770         NSTNS=4
00780          IF(ID(4).EQ.0) NSTNS=3
00790         NYEARS= LASTY-FIRSTY+1
```

Table C.1 (Continued)

```
00900 C
00910 C     INITIALIZATION...
00920       DO 500 I=1,NSTNS
00930       DO 500 J=1,NYEARS
00940       DO 500 K=1,12
00950       DO 500 L=1,3
00960 500   MD(I,J,K,L)=MISSNG
00970 C
00980       DO 510 I=1,4
00990       NAMN(I)=BLK
01000       IF(NORDER(I).NE.0) NAMN(I)=NAM(NORDER(I))
01010 510   CONTINUE
01020 C
01030       WRITE(6,30) FIRSTY,LASTY,ID
01040 30    FORMAT('1YEAR DATA STARTS: 1',I3,'  YEAR DATA ENDS:  1 ',I3/
01050      *       ' STATION TO BE ESTIMATED, ID: ',I3/
01060      *       ' STATIONS TO BE USED TO ESTIMATE D''S DATA:     STNA: ',I3,
01070      *'     STNB:',I8,'     STNC:',I8/)
01080 C
01090 C
01000 C
01010 C
01020 C
01030 C
01040 C
01050 C
01060 C
01070 C
01080 C
01090 C
01100 C      READ DATA FOR STATIONS WITH NEW FORMAT.
01110 C
01120 1700  NSDE=0
01130       READ(2,2,END=2100) ISTN,IYR,IEL,PRECIP
01140 2      FORMAT(I7,2I3,12(F6.1,1X))
01150       DO 2000 I=1,NSTNS
01160       NXT=NORDER(I)
01170       IDNXT=ID(NXT)
01180 1750  IF(ISTN.LO.IDNXT) GO TO 1800
01190       READ(2,2,END=2100) ISTN,IYR,IEL,PRECIP
01200       GO TO 1750
01210 1800  NSDE=NSDE+1
01220 1850  IF(IYR.LT.FIRSTY) GO TO 1900
01230       IF(IYR.GT.LASTY) GO TO 1900
01240       IYR=IYR-FIRSTY+1
01250       IEL=IEL-47
01260       DO 1860 MON=1,12
01270 1860  MD(NXT,IYR,MON,IEL)=PRECIP(MON)
01280 1900  READ(2,2,END=2100) ISTN,IYR,IEL,PRECIP
01281        IF(ISTN.EQ.4055085)ISTN=4055080
01282        IF(ISTN.EQ.4019080)ISTN=4019070
01291
01300       IF(ISTN.EQ.IDNXT) GO TO 1850
01301 2000  CONTINUE
01310 2100  IF(NSDE.EQ.NSTNS) GO TO 2500
01320       WRITE(6,33) NSTNS
01330    33 FORMAT('-ERROR: DID NOT ENCOUNTER DATA FOR',I2,
01340      *   ' STATIONS ON "NEW FORMAT" TAPE(S)')
01350       STOP
01360 C
01370 C
01380 C
01390 C
01400 C
01410 2500  CONTINUE
01420 C
01430 C
01440 C
01450 C
01460 C
01470 C
01480 C
01490 C
01500 C
01510 C
01520 C
01530 C     E S T I M A T I O N
01540 C                          WORKING ON ONE MONTH AT A TIME, ONE ITEM A
01550 C               A TIME.
01560 C               STATION D'S DATA IS TO BE ESTIMATED FOR EACH SUCCES
01570 C               MONTH.
01580 C
01590 C
01600 C
01610 C
```

Table C.1 (Continued)

```
01610         DO 6000 IMON=1,12
01620         DO 6000 ITM=1,3
01630         WRITE(6,35) MONTH(IMON),ITMTYP(ITM)
01640      35 FORMAT('-***',A4,'***',A8,'***')
01650         NOGAPS=0
01660 C       NOGAPS= # GAPS IN Q'S DATA FOR THE MONTH, IMON,  ITEM, ITM.
01670         DO 2620 IYR=1,NYEARS
01680         IF(MD(1,IYR,IMON,ITM).GE.0.0) GO TO 2620
01690         NOGAPS=NOGAPS+1
01700         OGAPS(NOGAPS)=IYR
01710 2620    CONTINUE
01720         IF(NOGAPS.GT.0) GO TO 2650
01730         WRITE(6,37)
01740      37 FORMAT(   9X,' NO GAPS TO BE FILLED')
01750         GO TO 6000
01760 C
01770 C
01780 C
01790 C
01800 C     (A)  CALCULATIONS:
01810 C                    1) FOR REJECTION CRITERIA (BASED ON 'N' OVERLAP
01820 C      YEARS)
01830 C         AN ESTIMATOR STATION, (A,B,OR, C) IS REJECTED IF 'RATIO'
01840 C                                (CALCULATED BELOW)  IS LESS THAN 'RLEVEL'
01841 C         WHERE RLEVEL=1
01850 C
01860 C              AND   2) FOR RELIABILITY TEST :  FOR EACH OF THE  N
01870 C               OVERLAP YEARS, STATION Q'S VALUE IS ESTIMATED.
01880 C                THEN, THE ACTUAL AND ESTIMATED VALUES ARE
01881 C                  COMPARED.
01890 C
01900 C       IN THE ARRAYS DESCRIBED BELOW, POSITION 1 IS NOT USED AND
01910 C            POSITIONS 2,3,4 REFER TO STATIONS A,B,C RESPECTIVELY.
01920 C      NOVRLP(I) = # YEARS OF OVERLAP BETWEEN STNQ'S AND STATION I'S DATA
01930 C      MOOVRN(I) = MEAN VALUE OF Q'S DATA OVER THE  N  YEARS OF OVERLAP
01940 C                               BETWEEN STN Q AND STN I,
01950 C      MXOVRN(I) = MEAN VALUE OF STATION I'S DATA OVER THE  N  YEARS OF
01960 C                               OVERLAP BETWEEN STN Q AND STN I,
01970 C      DIFVAR(I) = DIFFERENCES IN VARIABILITY FOR STN Q & STN I,
01980 C      SE(I) = STANDARD ERROR FOR STN Q & STN I,
01990 C      RATIO(I) = RATIO (RE: REJECTION CRITERION) FOR STATION I,
02000 C      CORREL(I) = CORRELATION OF Q'S ACTUAL AND ESTIMATED (USING STN I)
02010 C      SEE(I) = STANDARD ERROR OF ESTIMATE (FOR Q'S ACTUAL AND
02020 C                                                ESTIMATED (USING STN I)
02030 C        VALUES WHERE I = 2,3,4  (IE, STATIONS A,B,C RESPECTIVELY).
02040 C
02050 2650    DO 3300 ISTN = 2,NSTNS
02060         SO=0
02070         SX=0
02080         N=0
02090 C       FIND  N  OVERLAP YEARS.
02100         DO 2700 IYR=1,NYEARS
02110         QI=MD(1,IYR,IMON,ITM)
02120         XI=MD(ISTN,IYR,IMON,ITM)
02130         IF(QI.LT.0.0.OR.XI.LT.0.0) GO TO 2700
02140         N = N + 1
02150 C       COLLECT DATA FOR OVERLAP YEARS:
02160         Q(N)=QI
02170         X(N)=XI
02180         SO=SO+QI
02190         SX=SX+XI
02200 2700    CONTINUE
02210 C
02220         IF(N.GT.1) GO TO 2800
02230         NOVRLP(ISTN)=N
02240         DIFVAR(ISTN)=0.
02250         RATIO(ISTN)=1.E20
02260         SE(ISTN)=0.
02270         GO TO 3200
02280 C
02290 2800    NOVRLP(ISTN)=N
02300         QBAR=SO/N
02310         MOOVRN(ISTN)=QBAR
02320 C
02330 C
02340 3000    IF(SX.EQ.0.) SX=0.01
02350         SQOSX=SO/SX
02360         MXOVRN(ISTN)=SX/N
02370         SQQ=0.
02380         SQLX=0.
02390         DO 3100 I=1,N
02400         QQ=QBAR-Q(I)
02410         QL=Q(I)-SQOSX*X(I)
02420         SQQ=SQQ+QQ*QQ
02430         SQLX=SQLX+QL*QLX
02440 3100    CONTINUE
```

Table C.1 (Continued)

```
02450       DIFVAR(ISTN)=SQLX
02460       IF(SQQ.EQ.0.) SQQ=0.01
02470       RATIO(ISTN)=SQLX/SQQ
02480       SE(ISTN)=SQRT(SQLX/(N*(N-1)))
02490       IF(RATIO(ISTN).GE.RLEVEL) GO TO 3200
02500 C       *FOR RELIABILITY TEST- PRECIPITATION DATA* COMPUTE Q'S ESTIMATED
02510 C        VALUES, QE,  FOR ALL STATIONS WITH RATIO .LT. RLEVEL.
02520       NM1=N-1
02530       DO 3110 I=1,N
02540       XNM1=(SX-X(I))/NM1
02550        IF(XNM1.EQ.0.) XNM1=0.01
02560 C        ***ESTIMATION  (PRECIPITATION) :
02570 3110  QE(I)=X(I)*((SQ-Q(I))/NM1)/XNM1
02580 1111  FORMAT('     Q',F8.2,'     QE',F8.2,'      X '
02581      *)                                                  ,F8.2,10F8.2/10F8.2/
02600 C       COMPUTE  SEE  AND  CORREL. COEF  FOR Q & QE.
02610 C            Q'S ACTUAL VALUES ARE DENOTED 'QA',  ESTIMATED VALUES FOR
02620 3150  SQAMQE=0.
02630       SQE=0.
02640       SQEQA=0.
02650       SQESQ=0.
02660       SQASQ=0.
02670       DO 3160 I=1,N
02680       QEI=QE(I)
02690       QAI=Q(I)
02700       SQE=SQE+QEI
02710       SQEQA=SQEQA+QEI*QAI
02720       SQESQ=SQESQ+QEI*QEI
02730       SQASQ=SQASQ+QAI*QAI
02740       QAMQE=QAI-QEI
02750       SQAMQE=SQAMQE+QAMQE*QAMQE
02760 3160  CONTINUE
02770       QEBAR=SQE/N
02780       QABAR=QBAR
02790       DENOM=(SQESQ-N*QEBAR*QEBAR)*(SQASQ-N*QABAR*QABAR)
02800       IF(DENOM.LE.0.) DENOM=1.E-70
02810       CORREL(ISTN)=(SQEQA-N*QEBAR*QABAR)/SQRT(DENOM)
02811       R=CORREL(ISTN)
02812       XX=1-R*R
02814       IF(XX.LE.0.) XX=1.E-70
02820       SEENM2=N-2
02830       IF(N.LT.3) SEENM2=1.E-70
02840       SEE(ISTN)=SQRT(SQAMQE/SEENM2)
02841       TT(ISTN)=R*SQRT(SEENM2)/SQRT(XX)
02850 C
02860       WRITE(6,46) NAM(ISTN),NOVRLP(ISTN),DIFVAR(ISTN),SE(ISTN),
02870      *                          RATIO(ISTN), CORREL(ISTN),SEE(ISTN),TT(ISTN)
02890     46 FORMAT(1X,A4,':  N=',I3,'  DIFF.VAR=',F8.2,'  SE=',F5.3
02891      *,' RATIO ',F5.3,' CORREL.COEF=',F5.3,' SE=',F5.3,' T TEST=',F5.2)
02900       GO TO 3300
02910 C
02920 3200  WRITE(6,36) NAM(ISTN),NOVRLP(ISTN),DIFVAR(ISTN),SE(ISTN),
02930      *                          RATIO(ISTN)
02940     36 FORMAT(1X,A4,':     N=',I3,'     DIFF.VAR=',F11.5,'     SE=',F11.5
02950      *   ,'     RATIO=',F9.5)
02960 3300  CONTINUE
02970 C
02980 C
02990 C
03000 C
03010 C
03020 C     (B)  DETERMINE WHICH STATIONS  CAN  BE USED TO DO THE ESTIMATION
03030 C               AND RANK THEM USING DIFVAR & SE.
03040 C
03050       NEST=0
03060 C     NEST= # OF ESTIMATOR STATIONS. (ARRAY "ESTSTN" CONTAINS THEIR
03061 C     INDICES.)
03070       DO 3330 I=2,NSTNS
03080       IF(RATIO(I).GE.RLEVEL) GO TO 3330
03090       NEST=NEST+1
03100       ESTSTN(NEST)=I
03110 3330  CONTINUE
03120       IF(NEST.GT.0) GO TO 3360
03130       WRITE(6,38) NOGAPS
03139     38 FORMAT(' NO STATIONS PASSED ESTIMATION CRITERIA:   ',I3,
03140      *                                                  ' GAPS REMAIN ')
03150       GO TO 6000
03160 3360  IF(NEST.LT.2) GO TO 3400
03170 C     RANK THE ESTIMATOR STATIONS...    (LOWEST DIFVAR FOR BEST STN, ETC
03180       L=NEST-1
03190       DO 3370 I=1,L
03200       K=I+1
03210       DO 3370 J=K,NEST
03220       DI=DIFVAR(ESTSTN(I))
03230       DJ=DIFVAR(ESTSTN(J))
03240       IF(DI.LT.DJ) GO TO 3370
03250       IF(DI.GT.DJ) GO TO 3365
03260       IF(SE(ESTSTN(I)).GT.SE(ESTSTN(J))) GO TO 3365
03270       GO TO 3370
```

Table C.1 (Continued)

```
03290 3365  M=ESTSTN(I)
03300       ESTSTN(I)=ESTSTN(J)
03310       ESTSTN(J)=M
03320 3370  CONTINUE
03330 C
03340 C      ESTSTN NOW CONTAINS THE INDICES OF ESTIMATOR STATIONS RANKED
03350 C      ACCORDING TO
03360 C       DIFVAR & SE.    (IE. ESTSTN(1) = BEST STATION.  ESTSTN(2)  2ND
03370 C                                                      ESTSTN(3)  3RD
03380 C
03390 C
03400 C      NOTE THAT 2 STATIONS ARE TO BE USED TO ESTIMATE    IF :
03410 C        SE (OF 2ND BEST AVAILABLE STATION)     IS LESS THAN
03420 C                                  SQRT(3)  TIMES  SE (OF BEST
03421 C                                    AVAILABLE STATION/
03430 C
03440 C          ('AVAILABLE' : THE STATION MUST HAVE DATA AVAILABLE FOR THE
03450 C                                                YEAR IN QUESTION).
03460 C
03470       DO 3380 I=1,L
03480       K=I+1
03490       DO 3380 J=K,NEST
03500       IEST=ESTSTN(I)
03510       JEST=ESTSTN(J)
03520       SEI=SE(IEST)*SQRT3
03530       SEJ=SE(JEST)
03540       TWO(IEST,JEST)=(SEJ.LT.SEI)
03550 3380  CONTINUE
03560 C
03570 C
03580 C
03590 C
03600 C
03610 C
03620 C    (C)  FILL IN THE GAPS WHEREVER POSSIBLE.
03630 C
03640 C     NGFILL= # GAPS FILLED
03650 3400  NGFILL=0
03660       DO 4000 I=1,NOGAPS
03670       IYR=OGAPS(I)
03680       OGAPS(I) = IYR-IFIRSTY+1
03690 C     DETERMINE WHICH STATIONS WILL BE USED TO FILL A GAP:
03700       IU=1
03710       DO 3500 J=1,NEST
03720       VAL(IU)=MD(ESTSTN(J),IYR,IMON,ITH)
03730       IF(VAL(IU).LT.0.0) GO TO 3500
03740       IUSE(IU)=ESTSTN(J)
03750       IU=IU+1
03760       IF(IU.GT.2) GO TO 3800
03770 3500  CONTINUE
03780 C
03790 C
03800 3600  IF(IU.GT.1) GO TO 3700
03810 C      GAP CANNOT BE FILLED.
03820       USED1(I)=BLK
03830       USED2(I)=BLK
03840       GO TO 4000
03850 C
03860 3700  NGFILL=NGFILL+1
03870 C      GAP FILLED USING STATION  IUSE(1)
03880       USED1(I)=ABRNAM(IUSE(1))
03890       USED2(I)=BLK
03900 C
03910 C        ***ESTIMATION  (PRECIPITATION) :
03920 C        NOTE THAT MXOVRN WILL NEVER BE 0. (SEE STMT 3000)  FOR PRECIP.
03921 C       ESTIMATION.
03930 3750  MD(1,IYR,IMON,ITH)=VAL(1)*MOOVRN(IUSE(1))/MXOVRN(IUSE(1))
03940       GO TO 4000
03950 C
03960 3800  IF(.NOT.TWO(IUSE(1),IUSE(2))) GO TO 3700
03970       NGFILL=NGFILL+1
03980 C      GAP FILLED USING STATIONS  IUSE(1) & IUSE(2).
03990       USED1(I)=ABRNAM(IUSE(1))
04000       USED2(I)=ABRNAM(IUSE(2))
04010       SE1=SE(IUSE(1))
04020       SE2=SE(IUSE(2))
04030       IF(SE1.EQ.0.) SE1=0.01
04040       IF(SE2.EQ.0.) SE2=0.01
04050 C        ***ESTIMATION  (PRECIPITATION) :
04060 3850  D1=VAL(1)*MOOVRN(IUSE(1))/MXOVRN(IUSE(1))
04070       D2=VAL(2)*MOOVRN(IUSE(2))/MXOVRN(IUSE(2))
04080 3900  MD(1,IYR,IMON,ITH)=(D1/SE1+D2/SE2)/(1./SE1+1./SE2)
04090 4000  CONTINUE
04100 C
04110 C
04120       WRITE(6,39) NGFILL,NOGAPS,(OGAPS(I),USED1(I),USED2(I),I=1,NOGAPS)
04130    39 FORMAT(I4,' OUT OF',I4,' GAPS WERE FILLED.     GAP(STN 1ST):  ',
04140      *       8(I4,'(',A1,1X,A1,')'),10(/3X,15(I4,'(',A1,1X,A1,')')))
04150 4100  CONTINUE
```

Table C.1 (Continued)

```
04160 C
04170 C
04180 C
04190 C
04200 C
04210 C
04220 C      WRITE OUT DATA FOR Q (WITH AS MANY GAPS FILLED AS POSSIBLE).
04230 C
04240       IDQ=ID(1)
04250       DO 7000 I=1,NYEARS
04260       IYR=I+FIRSTY-1
04270       DO 7000 ITM=1,3
04280       WRITE(3, 50) IDQ,IYR,ITM,(MD(1,I,IMON,ITM),IMON=1,12)
04281 50    FORMAT(I7,2I3,12(F7.1,1X))
04283       WRITE (6,51) IDQ,IYR,ITM,(MD(1,I,IMON,ITM),IMON=1,12)
04285 51    FORMAT(1X,I7,2I3,12(F7.1,1X))
04290 7000  CONTINUE
04370       STOP
04380       END
04390 //GO.FT02F001  DD DSN=SKG2HM.PRECIP,UNIT=SYSDA,DISP=(OLD,KEEP)
04400 //GO.FT03F001 DD DSN=SKG2HM.ESTIM4,UNIT=SYSDA,DISP=(MOD,KEEP),
04410 //  SPACE=(TRK,(50,5),RLSE),DCB=(RECFM=FB,LRECL=110,BLKSIZE=3300)
END OF DATA
```

*This program was originally written by D. Etcheverry (1978, SaskCOMP) as instructed by the author. It was then modified for use with the new climate data format, restricted to precipitation and updated by the author.